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A. 29 FT. 8 IN.
B. 39 FT. 8 IN.
C. 49 FT. 8 IN.

GOING FROM SEA LEVEL TO SANTA FE, A SHIP'S LANDING SPEED WOULD

A. STAY THE SAME
B. INCREASE
C. DECREASE

THESE WEATHER MAP ISOBARS ARE MEASURED IN

A. INCHES OF MERCURY
B. WEIGHT PER SQ. FT.
C. MILLIBARS OF FORCE

THE UPDRAFTS CAUSING CUMULUS CLOUDS ARE CALLED

A. EDDIES
B. THERMALS
C. ISOTHERMS

THIS SAYS IT'S A GOOD DAY FOR

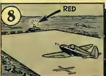
A. DUCKS
B. ICE-SKATES
C. KITES

THIS TRIANGLE ON A WEATHER MAP SIGNIFIES

A. SHOWERS
B. FOG-PATCHES
C. ICE-BURGS

THIS SIGN ON AN AIRWAY MAP MARKS

A. HIGH ALTITUDE EXPERIMENTAL STATION
B. HIGH EXPLOSIVES
C. HIGHWAY AIR-MARKER



A RED LIGHT FROM THE CONTROL TOWER MEANS

A. GO TO YOUR PORT
B. GO TO YOUR STARBOARD
C. DON'T LAND

THE NAUTICAL MILE EQUALS

A. .97 STATUTE MILE
B. SAME AS LAND MILE
C. 1.15 STATUTE MILE

Answers to this Air Age Refresher Quiz will be found on Page 58.

Flying CADET

VOL. 2, NO. 1 **JANUARY, 1944**

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J. D. Freudy, *Associate Editor*

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ON THE COVER

Loading deadly missiles into a Lockheed P-38 Lightning. These bullets are entering upon the last lap of their grim journey to the war front where they will strike at the heart of the enemy.

PHOTOGRAPH CREDITS

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The Superlative Spitfire

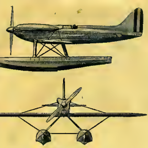
WHAT England owes to her Airmen, few can even estimate! But what those airmen owe to the deadly, all-metal Spitfire, the German Luftwaffe can very well estimate—much to their sorrow. This deadly little number, the fastest flying plane in the world, has sadly decimated the ranks of the Nazi Supermen's Air Armada.

Who created the Spitfire? Who, indeed, but Reginald Mitchell, whose far-sighted genius gave England's R.A.F. such fiery and deadly fighters in which to prove their skill and daring.

Now Reginald Mitchell is dead. He did not live to see his plane prove its superlative worth. But his plane lives on. It lives on in a faster and more aggressive way than ever for today a super-model of Reginald Mitchell's basic fighter design ranges the skies of England and Europe, to strike well-justified terror into the hearts of enemy airmen.

At the end of this war the Vickers Supermarine Spitfire will be the oldest fighter plane type in action. And it will have earned the title of the most remarkable all round single seater fighter in the air. Who will deny its share in battering the Luftwaffe during the Battle of Britain?

An idea on a designer's drawing board in 1932, a partial failure in 1933, the first Spitfire flew in 1936, with a fixed pitch airscrew. It had a maximum speed of 346 m.p.h., at 17,500 feet. In 1938, modified to carry eight 303 Browning machine guns, and fit-



SIRE OF THE "SPITFIRE," SUPERMARINE S-6B

THE FIRST "SPITFIRE" FLEW IN 1936

Maximum Speed 346 MPH at 17,500 Feet.

by KEITH AYLING

Former R.A.F. pilot and author of "They Fly for Victory."

basic design produced superlative aircraft, the Spitfire is a shining example.

Reginald Mitchell, its creator, who died before his plane went into action, started life as a designer of railway engines. He believed in steel construction and streamlining. He had the ambition to build the fastest and strongest plane in the world.

While designing huge flying boats for the Supermarine Company of Southampton, England, this quiet, sandy haired young man was dickering with racing seaplanes, to compete in the Schneider Cup International trophy. His first attempt was a failure, because of wing flutter. This cantilever float monoplane, built without any external bracing wires, raised the world's speed record to 226 m.p.h. in 1925. Later it crashed at Baltimore through wing flutter, and the Italians won the Schneider Cup.

Mitchell went back to England determined to do better. In 1927 his Supermarine 35 with a tubular steel center section and a one piece wing won the trophy at 281 m.p.h. The same ship later raised the world's float plane unofficially to 319.57 m.p.h. Mitchell was not satisfied. He wanted a faster, stronger machine.

For the 1929 Schneider Trophy he built the machine that was actually the sire of the Spitfire. This was the S6, an all-metal, low-wing monoplane with a 12-cylinder Rolls-Royce engine. Among its novel features were radiators built into the wings, an oil tank in the fin, and oil coolers along the line of the fuselage. The machine won the race at 328 m.p.h. Later it put up a world's speed record of 357 m.p.h.

A subsequent modification of the S6 was fitted with a specially boosted 2000 h.p. Rolls-Royce engine. This plane (called the S6B) flew over the Schneider Cup course at 340 m.p.h. Later, Flight Lieut. George Stainforth of the R.A.F. became the first human being to fly at more than 400 m.p.h. by raising the speed record to 407.5 m.p.h.

When the British Government wanted a single-seat fighter, they sent for Reginald Mitchell and gave him their specifications. The restrictions of the specifications were a considerable handicap. The first machine Mitchell produced, the S7/30 with a 660 h.p. engine, was a failure. His directors knew he could do better and gave him permission to design his own fighter plane. Finally he produced the first of the Spitfires,

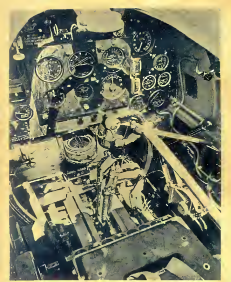
CONTINUED ON NEXT PAGE

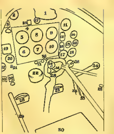
ted with a three-blade, variable-pitch propeller, the second model Spitfire became the standard single seater fighter of the R.A.F. Powered by a Rolls-Royce 12-cylinder Merlin, giving a maximum of 1,030 h.p at 16,250 feet, it was credited with a speed of 367 m.p.h. at 18,000 feet.

It was then the fastest and most heavily armed fighter plane, with a maneuverability that could not be equalled by the German ME-109. A stripped version of the ME-109 had raised the world's land plane speed to 379 m.p.h. With its armament, the original ME had a maximum speed of 354 m.p.h. To better this, the Germans clipped its wings; but the Spitfire with its 36-foot span could even then (and still can) turn inside the best of the German fighter planes, including the F.W. 190.

Up to date, there have been no fewer than twenty-two types or modifications of the original Spitfire, the latest to be mass-produced being the Spitfire IX, powered by a two-stage supercharged Merlin 61.

The Spitfire has been flown by British, American, Russian, Polish, French, Czechoslovakian, Dutch and Norwegian pilots. It has been used as a day-flying interceptor, as a bomber escort, as a deck-landing fighter, as a photographic plane and as a sea-rescue craft. It has been catapulted from the decks of merchant ships, and there is a special version adapted for low flying and troop strafing. If ever a good





1. PLATFORM FOR GUN-SIGHT
2. FLAP POSITION INDICATOR
3. FLAP LEVERS
4. INSTRUMENT FLYING PANEL
5. AIR-SPEED INDICATOR
6. ALTIMETER
7. DIRECTION INDICATOR
8. ARTIFICIAL HORIZON
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35. SELECTOR LEVER FOR UNDERCARRIAGE
36. PNEUMATIC BRAKE LEVER
37. AIR PRESSURE CONTROL FOR PNEUMATIC SYSTEM (GUNS AND BRAKE)
38. FUEL COCK

INSTRUMENT PANEL of a Spitfire. Like those of other modern planes this panel convinces you that the pilot had better know his business.

which, with four-gun armament, could achieve 346 m.p.h. at 17,500 feet!

Then came the touch of genius of a far-thinking man—the genius that saved England from being overwhelmed by the German Luftwaffe. Sir Hugh Dowding, Air Marshall, an ex-artillery officer, chief of Britain's Fighter Command, sent for Mitchell. He told him he wanted a fighter plane that would carry eight guns, instead of four. Mitchell went back to Southampton, worked day and night, juggled expertly with his stresses and wing-loading. The result was the Spitfire with a wing-loading of 24 lbs. to the square foot, and a span four feet greater than that of the ME-109, but four feet less than that of its stable-mate, the far-famed and highly maneuverable fabric and metal Hurricane.

The Spitfire is a good example of simplicity in fighter plane design that sacrifices nothing in rigidity. Mitchell streamlined his machine to give the minimum drag. He learned to give the smallest possible outline behind the motor. He made it extraordinarily light, its fully loaded weight being under 6000 lbs. He designed it so that it could be built in parts in dispersed factories and quickly assembled.

The secret of his success would seem to be his experience in the building of light, fast craft, and his refusal to sacrifice maneuverability for speed. Instead he maintained speed by the all-round elimination of drag.

From its very earliest tests, the little fighter made good. It was incredibly fast for its day, and it could be thrown about as easily as the old Gladiator biplane, the R.A.F.'s biplane fighter, that could be turned on the proverbial dime. The Gladiator was the most maneuverable fighter plane of its day.

Plans were made immediately to manufacture the new Spitfire in dispersed factories. Sub-contractors were put to work in various parts of England, Scotland and Northern Ireland. Tail units were made in one piece, under-carriage parts in another, and the main section of the fuselage elsewhere. While the machinery of manufacture was being arranged, improvements of design were effected, the most notable being the fitting of a three-blade variable-pitch propeller in place of the two-blader.

The Spitfire wings are fabri-

cated of light alloy. They are elliptical and taper in thickness An interesting feature of the construction is the single spar wing attached to the stressed skin fuselage. The spar is located far forward and the bottom engine bearers are attached to the cross member, as well as the undercarriage unit struts

Notice in the illustrations how the engine itself seems to be cradled by the bearers, with the stress of the upper members of the engine bearers being taken by the upper longeron to the fuselage, which is strengthened by its stressed skin On leaving the center section, aft of the pilot, the top longerons taper to an end, while the bottom longerons, made of lighter material, continue to the end of the fuselage The leading edge of the wing is covered with heavy gauge light alloy stressed over the spar web To the rear of the spar, the covering is of thinner gauge with light alloy girder ribs. Wing tips are detachable There are split flaps between the ailerons and the fuselage. Control surfaces are fabric covered.

The metal skin of the fuselage, which has eight traverse frames or bays, is flush riveted, and the bulkhead between the pilot and the engine is fireproofed.

The tail unit is detachable and consists of a cantilever metal tail plane, with the fin built into the tail-end of the fuselage member. The elevator and rudder are fabric covered over light alloy framework The retractable undercarriage is operated by hydraulics with a manual device in case of emergency

The Rolls-Royce engine fitted to the Spitfire has a story in itself. Its creator, Charles Rolls, who originally made bicycles, built his first automobile in 1904 and decided to continue to build the world's best automobile regardless of expense. By 1910, when he was killed flying a French airplane, the reputation of the name of Rolls was established, and his partner, Henry Royce, decided to preserve the name of his brilliant associate.

In World War I, the British Government called on the Rolls-Royce company to make engines for "blimps." From these engines, hurriedly converted from the automobile power unit, there came the 375 Rolls Falcon which had twelve cylinders arranged in V shape The Falcon was the father of the present Merlin. It was an astonishing engine, powering the fabulous Bristol Fighter and the Handley-Page V/1500, Britain's first heavy bomber, one of which flew from England to India. Brown and Alcock, who made the first non-stop East to West Atlantic crossing, used these engines.

After the Falcon came the 700 h.p. Kestrel, and finally the Merlin, which for its weight per horsepower stood ahead of all competition The Merlin is built in the same painstaking way as the Rolls-Royce automobile engines. Into it went years of experience, and the best materials available, with what seemed to be a total disregard of man-hours. The original Spitfire was fitted with the Merlin 11-V liquid cooled engine rated 990 h.p., giving a maximum output of 1,030 h.p. at 16,000 feet, and driving a three-bladed De Havilland

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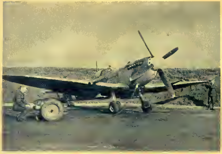
READYING A SPITFIRE IX on a field in North Africa. These nimble little fighters with their highly concentrated firepower may claim a large share of the credit for Allied victory in North Africa.



SPITFIRE WARMING UP for take-off. The improved Spitfire now in service has four-bladed propellers and a radiator under each wing.

air-screw of variable pitch.

Fitting such a big power unit into the slim fuselage of the Spitfire called for an all-round display of ingenuity Mitchell achieved it by rigidly abolishing bumps and ungainly contours. He put the cooling radiator under the starboard wing, with hinged flaps for heat control. The oil tank was cunningly fitted underneath the engine to form part of the body contour. The fuel tanks, each of 85 gallons capacity, were carried between the pilot's instrument board and bulkhead and the engine, protected by the engine itself and armor.

Such was the redoubtable Spitfire flown by the R.A.F. pilots who shattered the Luftwaffe, with incredibly low losses. With an unheard of rate of climb at something exceeding 2,300 feet a minute in its initial stages, and a service ceiling of 35,000 feet, the little Spitfires streaked across the skies and slaughtered the Heinkels and Dorniers that Goering dispatched to shatter Britain's coastal defenses.

Able to outfly and out-maneuver the ME-109 and the Heinkels, the Spitfire pilots ignored the German fighters and tore into the bomber formations. In order to catch up with the Spitfires, the Germans took off the wingtips of their ME-109's, but while this increased the ME's speed in straight flight, it did not help its maneuverability because it increased its wing loading. The Spitfire could still turn inside the ME.

While the Spitfires proved themselves in the air, the designers were busy on improvements. They wanted more power, heavier armor and armament. The Spitfire was an old machine, but its basic design was sufficiently good to justify the Vickers' management belief that heavier loads and greater speed and climb could be obtained without major structural alterations. Modifications were made to both machine and engine Some of these passed almost unnoticed. The use of high octane fuel stepped up the power and an improved radiator was fitted

An indication of the improvements brought about in the first Merlin engine is that the Merlin XX, predecessor of the new 61 produces 250 h.p. with the identical cylinder capacity of the former type.

Sundry changes were constantly made in the Spitfire's armament. Some models were fitted with two 20 mm. cannon and a complement of machine guns, some had four 20 mm. guns, others twelve machine guns. Some were equipped for use in the desert. Others were made for use in cold regions. One model called the Seafire, fitted with a tail hook and increased width of undercarriage, was put into service as a carrier-born fighter.

It was not until the design had reached the Spitfire V stage that any marked difference could be seen in the exterior. The first Spitfire V was fitted with a Rolls-Royce Merlin 61 instead of the 45, or the 46 (a souped up version of the former). The fitting of this engine with its two stage super-charger involved the fitting of a slightly longer nose and larger spinner, the supercharger intercooler being directly behind the engine. A four bladed variable pitch propeller was fitted and armament was two 20 mm. cannon and four machine guns housed in the wings and firing outside the propeller arc.

It was at the Spitfire V stage that other modifications were made. The Spitfire Vb made its appearance early in 1943, as a low-level fighter and ground attack plane, probably for Britain's Army Co-operation Command This machine has clipped wing-tips, giving it a span of 32 feet 2 inches. Like the other V's, it has a large radiator under the starboard wing, with an oil cooler under the port wing. The removal of the wing-tips increases the wing-loading. While giving extra speed by eliminating drag, it decreases maneuverability.

With its engine tuned to give major power at minimum altitude the Vb probably exceeded the V's speed of 397 m.p.h. under 12,000 feet. Whether these machines have been widely used is not known, but they will doubtless figure largely in any invasion of European coasts that may be undertaken in the coming year.

With Germany threatening to build bombers for high altitude jumping over Britain's aerial defenses (such as the Ju 86 pressure cabin machine and the four engined Heinkel 177) the British turned their attention to producing a high altitude super Spitfire. This is the present Spitfire IX, so secret that its actual dimensions are still on the secret list.

EAGER TO START a day's work, pilot gets settled in his cockpit.

In this model modifications have been made to the cockpit, new type flat radiators are carried far back under each wing, and an extra streamlined fuel tank is carried under the belly. The wings have been slightly modified, having a less curved leading edge; the windscreen has an augmented rake and the cockpit cover is smaller. The wings are constructed to carry two or four cannon-firing guns, and the spinner seems unusually large. The propeller is a four bladed constant speed all-metal Rotol.

The new Rolls-Royce 61 is slightly longer than the Merlin XX because of the position of the supercharger intercooler. It weighs approximately 1600 lbs. as compared with the 1450 lbs. of the previous model. The only outstanding modification in design is the use of the two-piece cylinder similar to that on the Merlin XX produced in U. S. by the Packard Company.

The Spitfire IX is intended for high altitude work. Two of these aircraft distinguished themselves during the test period by shooting down three of Germany's latest Ju 86 pressure cabin reconnaissance bombers at a height exceeding 45,000 feet—a remarkable achievement in view of the fact that the Spitfire cabins were not pressurized! The Spitfire pilots, who suffered badly from "bends" and nausea, reported that the temperature in their cockpits fell to 67 degrees below zero. In each case the British planes ran out of gas, but all the pilots succeeded in landing safely, having proved to the Germans they would have to fly much higher if they wanted to jump on Britain's aerial defenses.

The Merlin 61 follows closely the main features of the original Merlin. It has twelve cylinders, set in V shape, each with a 5-4 in. bore, a stroke of 6 in. and a capacity of 1,649 cubic inches (or 27 liters). The compression ratio is 6 to 1.

The supercharger is of the two-stage mechanically operated variety, as opposed to the turbo-supercharger used by U. S. radials. A supercharger or blower feeds air and gasoline vapor to an engine under boost pressure. In considering supercharging problems it must be remembered that weight of fuel and air is more important than volume because volume varies with air pressure, which varies with altitude.

The object of using a two-speed drive for a supercharger is to speed up the rotating impeller at high altitude, to insure a greater volume of less dense air so as to give the essential weight of fuel charge to the cylinders.

In the two-stage supercharger fitted to the Merlin 61, the mixture of gasoline and air is compressed in the first stage, and then forced into the container of the second stage, where it is further compressed before being delivered to the induction pipe.

The compression of the quantity of air necessary for the combustion of the gasoline demands a great amount of power which in its turn heats the charge. The generation of heat in a supercharger is similar to compression of the air in a bicycle pump, which gets exceedingly hot when pumped vigorously against high pressure in the tire. In order to obtain the greatest benefit of the fuel charge, this must be kept cool. This is achieved by passing the heated charge through a series of pipes known as the intercooler, before delivery to the cylinders.

The new Spitfire IX owes its superlative quality to the fact that the Vickers' designers have been able to concentrate on increased power and propeller thrust, without departing materially from Reggie Mitchell's original design.

In the first place he designed a "clean" airplane on sound principles, without going into the heavy class. The Spitfire, according to some experts is the only fighter plane that could go into a dogfight with the Jap Zero and outmaneuver it. That test is yet to come. One thing is sure, when the Spitfire does meet the Zero, it will prove itself ten times as tough as the nimble Japanese fighter, which lacks the ability to stand up to punishment.

Spitfires have to take as well as give. During the Battle of Britain some of these machines returned to their bases battered by cannon shells and peppered with machine gun pellets, but they came back, while a less sturdy machine would have crashed! One pilot reported a collision with a German bomber. He regained his airport minus a wing tip, which, as the report of the happening stated, "was detachable anyhow."

The early Spitfires lacked sufficient all-round armor for the pilots, and many fliers were wounded in the feet and ankles. This was quickly corrected, and the present type is generously fitted with high quality armor plate.

The success of the early Spit-

CONTINUED ON NEXT PAGE

THIS FIRING BUTTON sends many a Nazi catapulting to doom.

SPITFIRE FIGHTER is bomber too. Note bomb racks in picture.

AWAITING ORDERS, V-C stands at attention on a Tunisian field

SPITFIRE V with two 20 mm. cannon, four machine guns in wings

CLIPPED WINGS characterize Spitfire V. These eliminate drag, thus increasing speed. Plane is less maneuverable, due to more wing loading.

fires was due to the eight machine guns which could discharge almost 10,000 rounds a minute. The Germans had fitted their fighters with a mixture of 20 mm. cannon and machine guns, and were caught short, by the daring of the R.A.F. pilots who flew in close to their targets and opened fire with their eight guns at ranges varying from 500 to 100 yards. Often a Spitfire pilot, getting on the tail of a bomber, would report that he had given his first burst at 400 yards, his second at 250, his final at 100. "After that," wrote one pilot in his intelligence report, "I was flying through the bits."

The eight guns of the Spitfire I were arranged to converge in a cone at 250 or 300 yards. At the focus point of all guns the 220 lbs. of bullets poured into the target at a kinetic energy of 2,300 foot pounds a minute. The effect was similar to that of a buzz-saw cutting through wood. The terrific concentration of fire power ripped large holes in the fuselages and engine cowlings of the enemy aircraft. A burst on the tail of an enemy fighter often neatly separated the *empennage* from the fuselage.

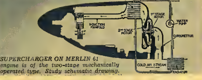
The Germans quickly modified their planes, even putting temporary armor plating in cockpits and round engine conduits, but the multiple hammer blows of the stream of bullets continued to triumph. Nothing could resist such a concentration of fire. One ME shot down over England had a gaping hole in the cockpit where the pilot's seat should have been. On several occasions the concentrated fire from the Spitfire guns shot the engines entirely out of Dornier and Heinkel bombers.

On the score of maneuverability the Spitfire started the air war with a strike in its favor. Its ability to tight-turn, the key to success in a dog fight, enabled the pilots to get inside the ME-109's and shoot them down.

In attacking bomber formations, the R.A.F. pilots evolved a seemingly perilous maneuver only possible with a machine of such high speed and maneuverability. When intercepting a bomber formation escorted by German fighters, the Spitfires made a feint head-on attack on the fighters, then broke off and dived on the bomber formation. In passing the flanking plane of the leading element of bombers the pilot delivered a burst of fire. Once past this plane, he would straighten out, and, climbing to the rear of the bomber formation, give a burst of fire at the belly of the outside machine of the tail-end element of the formation, climbing at high speed underneath the machine's tail. Once clear, the pilot yanked the Spitfire over in a tight half-loop, half rolled at the top and came down in a dive on the rear of the remaining two planes in the rear formation, giving each a burst. Using this maneuver, some pilots knocked off four bombers, some three with a burst for each plane, and made good their escape before the bombers or their fighter escorts could fire a single burst.

Of all fighter planes in the air, the Spitfire is probably the pilot's pet, because it is capable of executing any maneuver taught in flying schools for advanced aerobatics. Unlike the FW-190 which the Luftwaffe hoped would outclass it, it does not go heavy on the controls at high altitudes, and it has no marked "bad habits". The position of the cockpit affords the pilot a fair degree of visibility, and its landing speed is low enough to enable it to function safely as a night fighter.

The principal disadvantage of the early models was the shortness of range. This would seem to have been eliminated in the Spitfire V and IX, because we read that Spitfires flown by R.A.F. and U.S.A.A.F. pilots accompanied our Forts and Liberators on the big raid on Lille in Northern France in October 1942. Fighter



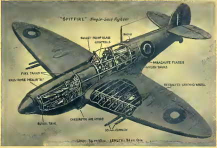
SUPERCHARGER ON MERLIN 61 engine is of the two-stage mechanically operated type. Study schematic drawing.

SPITFIRE V

SPITFIRE IX

SPITFIRE V-C

SPITFIRE IX IS HIGH CLIMBING super-Spitfire with 4 cannon-firing guns. Plane can take as well as give. It is fitted with high quality armor.



CUT-AWAY PLAN OF SPITFIRE V showing internal construction. This V has longer nose than previous models. Engine is a Rolls-Royce Merlin 61.

pilots of the U. S. 8th Air Force stationed in Great Britain made their debut against the Luftwaffe flying Spitfires, and were similarly mounted in North Africa. All of them were enthusiastic about the machines.

As a fighter-plane maid-of-all-work the Spitfire fills in with a variety of jobs. It is used as photographic machine for both high and low altitude work, and is also employed by the R.A.F. sea rescue service. These machines are fitted with dinghy and first aid containers carried in release chutes under the belly of the fuselage. The chutes face to the rear of the plane. On reaching the ditched pilot the rescue flier presses a release and the chutes are ejected by a spring device.

For photographic work the Spitfires fly stripped of all armor and armament. No figures are available as to performance of these machines, but it can well be imagined that they have clocked up some staggering figures for speed and altitude. During the preliminary stages of the North African campaign photographic Spitfires equipped with belly-tanks to increase their range undertook reconnaissances over extremely long range, penetrating deep into Vichy-held territory. Similarly many of the photographs of bomb damage over Germany have been secured by these machines flying at stratosphere altitudes.

In the latest Spitfire IX the British have aimed at countering any move the Germans may have had in mind of making a concentrated high-flying attack on England as a counter-stroke to the expected land invasion of the European coast. The IX's are said to be faster at high altitude than the FW-190 and the new ME-109G or the H, which is a high altitude version of the present G model of what is Germany's best all-round fighter. The last stages of the air war may be fought at 40,000 feet. However high the battlefield selected by the Luftwaffe for a final test of strength between its fighter planes and those of the allies, the Spitfire will be there. And so the descendant of the little seaplane that broke the world's records so consistently, will be striking its deadly blows at Hitler's airmen, until the end. No wonder the British are proud of their superlative Spitfire!

"CLOSE BOMB BAY DOORS" is what Mechanic Roland Wentzel, with an upsweep of the hands, is telling the man in the plane. The men are ground-testing the engine of this Grumman Avenger torpedo bomber.

DEAFENED BUT NOT DUMB

GROUND-TESTING the engines of Uncle Sam's warplanes is such a noisy business that mechanics at a Grumman plant have devised an ingenious and expressive sign-language combining pantomime and hand signaling and ranging from dramatic seriousness to what might ordinarily be hilarious comedy. By a swift motion and a facial contortion, a message is relayed in a split second, saving the time and effort needed to cut the engines, listen to a diagnosis of the trouble and start the motor up again.

These pictures show some of the signals commonly used by the "actor"-mechanics.

CONVEYING MESSAGE that "Carburetor mixture is too lean," mechanic places two fingers on each cheek.

FLAPPING ARMS FORWARD, as mechanic is doing, is part of signal which is completed in the next picture.

THUMBS UP means the same thing in any language, so it's easy to understand this "OK to start fight!"

FLAPPING ARMS BACK finishes the story, telling the man to "Fold wings." Darned clever, these mechanics

DEAFENED, BUT NOT DUMB

"CUT THE ENGINE" is all that's meant by this gesture, which the uninitiated might interpret quite differently.

ADDING THE HANDY SIGN of Ballantine fame to the throat-cutting signal means "Oil leak—cut the engine!"

OK TO START the engine is a typical "On Your Mark" signal.

"ENGINE SMOKING" is shown by holding an invisible cigarette.

SUCH PANTOMIME speaks for itself. It says "Mixture too rich."

INCREASE RPM (Revolutions per Minute) is indicated by bending forearm and pushing it away from body.

MAKING LIKE A DUCK'S BILL with his hands, this mechanic signals his co-worker to "Increase vacuum."

LOOK AT THIS assembly line! Propeller-making is no small job.

WHIRL AWAY

GIANT PROPELLER DESIGNED for bombers and troop transports which must brave the stratosphere. This picture shows the world's very largest propeller undergoing stringent tests in the testing chamber.

AFTER the infamous bombing of Pearl Harbor, the United States was left momentarily reeling from shock and incredulity. But bewilderment quickly became anger. Swiftly and furiously she rallied, mustered her forces and took stock of herself—to face a sorry state of affairs, indeed. For she was forced to admit the unhappy fact to which she had previously turned a deaf ear—that her up-to-date fighting aircraft and equipment was far too inadequate to be of much use in stemming the onrushing tide of Axis conquest.

The enemy, fully aware of this, felt confident it could knock the United States out of the war before its Air Forces (then in the embryo stage) could be built into a formidable fighting unit.

But Hitler and his satellites were bum guessers. Daily communiques from today's fighting fronts contain conclusive proof that United Nations' pilots in American-made aircraft are taking a one-sided toll of the best fighting planes the Germans and Japs have been able to put into the air. Our bombers, almost unimpeded, are blasting the enemy into submission in every sector.

Today, little more than a year and a half after we entered the war as an active participant, the U. S. Air Forces are second to none, ally and enemy alike, in personnel and in equipment. Our war plants are turning out materials which surpass the combined output of the enemy.

And Curtiss Electric Propellers, the saber-like, hollow steel blades which are propelling our fighters and bombers (and those of our Allies) through the skies over every battle theater on the globe, are playing a leading part in the superb performance that has given American-made planes

WINGED BEAUTIES in flight. All three have Curtiss propellers.

the air superiority they now enjoy.

It is a far cry from the old, wooden, fixed pitch propeller to the electrically controlled, constant speed, metal propeller developed by the Curtiss Propeller Division for powerful, high altitude, long range fighter, bomber and troop transport planes. However, during aviation's forty year span (the Wright brothers made their first sustained flight in 1903) the basic function of the propeller has remained unchanged—to propel the plane through the air.

The propeller is as much a part of the plane's power plant as is the engine, but this seldom is appreciated by those outside the fields of aviation engineering and aerodynamics, because the whirling blades are virtually invisible when doing their work best. In the final analysis, the propeller, which converts engine power into the thrust needed to fly a plane, is a primary factor in determining the speed at which the aircraft can cut through the air.

Its job can be compared to that of the transmission and rear wheels of an automobile—to absorb engine power and to convert this power into forward motion.

For instance, if the angles of the blades of a Curtiss full feathering propeller are likened to the various gear settings of an automobile, we can draw a direct comparison. Low gear on a car is utilized to start off—low blade angle is used when the plane is taking off; medium blade angle corresponds to second gear, and the greatest blade angle to the automobile's high gear.

However, electrically controlled propellers differ from a car's transmission in that it is not necessary to shift gears for the various conditions of flight. Such shifting or blade angle changing, which enables the airplane engine to maintain constant speed whether climbing, cruising or diving, is handled by a governor which automatically operates the blade pitch-changing mechanism.

Propellers used in World War I were of the fixed pitch type, and their only requirement was to convert the power of the engine into pull, or thrust, while the modern propeller plays a versatile role in the operation of its aircraft.

In addition to providing thrust, it now maintains constant speed of the engines and to a certain extent, regulates gasoline consumption, thereby providing maximum efficiency with minimum fuel consumption.

Like everything else about the modern airplane, propellers must be durable and light in weight. Hollow steel blades are proving the answer. A three-blade propeller, 11 feet in diameter, would weigh 315 pounds with hollow steel blades, and 355 pounds with aluminum alloy. Additional weight savings can be obtained through the use of a propeller employing wooden blades which, in the 11 foot diameter category, weigh approximately 290 pounds. But greater strength and durability make hollow steel blades more desirable.

Curtiss Electric Propellers are adjustable over a wide range of angles to meet all operating conditions. The high pitch settings provide for high speed at sub-stratospheric altitudes and limit engine speed during dives, a highly essential requisite for dive bombers and fighters. The range of these electrically operated propellers is unlimited and, therefore, control may be maintained through any position from reverse to feather, and easily adapted to any operating requirement.

In addition to leading the transition from wood to metal blade, Curtiss also perfected a six-blade dual rotation propeller, the first in the world to be built around the principle of electric control of the blades. It was especially designed for powerful fighter planes.

Durability of hollow steel blades was proven in a dispatch received from an American Fighter Squadron captain who said eleven inches had been severed from the tip of one of his Warhawk's Curtiss Electric propeller blades when it whacked the armored turret of a German tank he was strafing. Despite the damage, he said, the propeller flew the plane safely back to base, a distance of 175 miles.

On a medium-size, three-blade Curtiss Electric propeller, the electric unit, which controls the blade angles, weighs approximately 40 pounds but accomplishes the work of a locomotive. For instance, the 50 ton centrifugal force set in motion by the rotation of this propeller exerts a tendency to flatten out the blade

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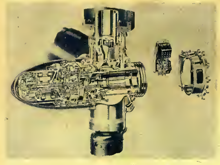
THIRTEEN FEET, SIX INCHES is the diameter of the constant speed, selective pitch, four-way feathering electric propellers used on this plane.

FULL FEATHER POSITION of the propeller on a B-26. In this position propeller blades of an inactive engine are parallel to direction of flight

PB2Y CORONADO, the giant flying boat of Consolidated Aircraft Co., is equipped with four 4-blade Curtiss Electric hollow steel propellers.



CUTAWAY VIEW showing reversion mechanism of 4-way hollow steel or aluminum alloy blade propellers. Curtiss principle permits turning blades all the way around into reverse angle. Four-blade types are used on fast, high altitude fighter, bomber and cargo planes, such as Republic P-47 Thunderbolt, Martin B-26 Marauder, and the Curtiss C-46 Commando.

—to twist it to a lower angle. Under some flight conditions, this force is as great as 5000 inch-pounds on each blade. Yet the three blades are turned to the proper angle and held there by this 40 pound unit.

There are three major parts of this power unit. First is the speed reducer, with its gear ratio step-down of approximately 9500-to-1; the electric pitch changing motor, and a magnetic brake.

The electric power unit also feathers the propellers when necessary. Feathering, a Curtiss development, can mean the difference between "returned safely to base" or "failed to return." With full feathering, the propeller blades of an inactive engine on a multi-engine plane are turned parallel to the direction of flight, preventing "windmilling" of the propeller on the inactive engine by holding the blades stationary, thereby reducing drag and preventing damage to the active power plant.

The latest Curtiss contribution to the aviation industry is a single control unit which promises to revolutionize the maneuverability of multi-engine aircraft. Recently developed and known as the Automatic Engine Speed Synchronizer, it already has undergone its baptism of fire on several fighting fronts.

This ingenious device, developed under the sponsorship of the Army Air Forces, relieves the pilot and flight engineer of flying battleships of periodic adjustments to constant speed propeller controls, thus enabling them to devote their attention to the great number of other details connected with flying these huge craft.

Without this automatic synchronizer, the pilot of a four-engine plane had to manipulate four separate levers, one by one, in order to synchronize the speed of the four engines, and had to rely on physical and mental precision to strike and maintain a speed setting.

Curtiss also developed a 16¾ foot hollow steel blade propeller, the largest ever to go into actual flight, and which exceeds in size anything yet produced by the enemy. It was primarily designed for high altitude bomber and troop transport planes which soar at altitudes where the air has only one third the density found at sea level.

Curtiss Electric Propellers are today flying such famous fighters and bombers as Republic's P-47 Thunderbolt which has more than proved a match for Germany's best, the Focke-Wulf; and Lockheed P-38 Lightnings, which pilots say "climb like a homesick Angel." This twin-engine interceptor has chalked up an enviable record against the Japs in the Southwest Pacific, in the Aleutians and in North Africa.

Among the array of other Curtiss-propelled fighting aircraft are: Martin B-26 Marauders, Martin Mariner, Curtiss C-46 Commando, the largest troop transport plane in the world, Brewster SB2A Buccaneer; Airacobras, Mustangs, Wildcats, Coronados and the Curtiss Warhawks, Kittyhawks and Tomahawks.

Such a list indeed speaks eloquently for itself.

The remarkable performance record of these propellers in combat, and how the Division pioneered in quantity production of the high-precision, hollow steel blade propellers was described recently by Colonel Howard H. Couch, Chief of the Propeller Laboratory for the Army Air Forces, following his return from a tour of African and European battlefronts.

He pointed out that it was much more difficult to develop manufacturing processes for hollow steel blades than it would have been to continue the manufacture of aluminum alloy blades from forgings.

"There weren't sufficient aluminum alloy forgings available. Someone had to tackle the job—and Curtiss did. To date, no other nation in the world has been able to manufacture hollow steel blades for combat airplanes in quantity—and plenty of them have tried!"

BATTLE OF THE BIGGIES

By A SPECIAL CORRESPONDENT

WILL the fighter plane which carries a rocket-gun succeed in beating the bomber? Or will a new version of the modern bomber, a veritable battleship of the air armed with rocket guns, cannon and heavy calibre machine guns, blast the fighter-plane from the air? Where will the nations go from that point, in the struggle for control of the vertical flank which is the key to victory?

War in the air has now reached its most dramatic and devastating stage. The battle between the heavy bomber and the interceptor fighter blazed to fury over Europe when the Fortresses and Liberators of the U S 8th Air Force dared to challenge the German FW-190's and ME-109's in daylight It has moved still another step forward

The Luftwaffe fighter planes were slaughtered mercilessly by the deadly barrages of 50-calibre machine gun fire of the U S flying porcupines But they are now carrying a new weapon, a gun firing a rocket-propelled projectile with an effective range of 2000 yards! Little is known about this new weapon except that it works on the same principle as our own U S Bazooka, which is doing such good work on German tanks on the ground, and which resembles Katusha, the Russian rocket gun.

The principle of the rocket gun is simple The projectile is discharged at low velocity by means of a spring or small charge, which has a minimum recoil. As the projectile leaves the tube or barrel of the gun, the rocket charge is ignited electrically As it explodes, the missile increases its velocity The use of several successive explosive charges gives the projectile a terrific penetrating power.

The latest FW-190 fighters, which Germany is using to defend her shattered industrial

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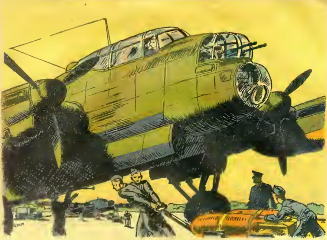

centers carry four of these guns under their wings. The pilots attack bomber formations in elements of three or four planes, in order to concentrate their fire. They discharge their missiles outside the range of the bomber's fifty calibre guns, and immediately take evasive action.

How accurate the new weapons are remains to be proved. The shells would seem to weigh about 12 lbs. Bombers hit by such a missile traveling at high velocity are not likely to survive, although a case has been reported of an American gunner, who picked up a rocket shell that penetrated the fuselage of his bomber, and hurled it through the bomb bay before it detonated.

Other fliers have reported that generally the aim of the new weapon leaves much to be desired, but it is admitted that it has increased the losses of Allied bombers in German-defended skies, particularly among the British heavies. A recently published picture of one of our Fortresses falling minus an entire wing might well be taken to indicate the result of a hit by one of these new weapons.

The aiming of the rocket shell calls for new and complicated sighting mechanism. Its low muzzle velocity tends to make the rocket drop on leaving the tube. The attacking pilot has to pull up the nose of his machine, at the moment of discharge. To do this he has a sight contrived on what the British call the "Christmas tree" principle.

To obtain a hit he needs to know the exact range and speed of the target. With little chance of being attacked by the bomber's guns, he can choose his firing position with comparative ease.

The Germans take full advantage of their immunity from counter-fire, and endeavor to get full deflection shots, the length of the bombers affording them the greatest target area. Four or more fighters concentrating in formation and releasing their projectiles simultaneously can create a cone of fire which would spell destruction for the bomber if the pilots aim correctly.

The story behind the production of the rocket-gun is one of the Luftwaffe's sheer desperation in countering the devastating Fortress raids. When the big bombers with their fifty calibre machine guns made their first appearance over Europe, they actually made 13 raids before losing a single ship. In those raids they destroyed or damaged some eighty German fighters. Then the Germans began to use new tactics and gradually the losses of the Forts and Liberators increased, although the figures have never exceeded five percent of the total planes employed.

At first the German fighters found that the big bombers flying in formation represented a deadly proposition. One notable exploit of Fortresses and Liberators was the Lille raid in October, 1942, when some 102 German fighters were knocked out of action, only five of them being attributed to escorting Spitfires. Four bombers were lost.

Then new German tactics began to tell. The Germans discovered that the Fortress was weak on front guns. They fitted heavy armor to the bellies of their ME 109's and FW 190's and made dive attacks from the front, the pilot turning his machine on its back at the moment of firing and thus giving the Fortress gunners only

THE LANCASTER, A BRITISH "BIGGIE" LOADING UP FOR THE NIGHT'S MISSION

a fleeting target of his armored belly. To hit a fighter plane doing 400 to 500 mph at close range is some feat.

Another device was to endeavor to cripple the bomber flying in the rear element (tail-end Charley) and make a concerted attack on this ship after separating it from the others. Similar attacks would be made on the bombers at the extreme edges of either flank. The attacks were costly, but they brought a measure of success. In June, 1942, the U.S. Army Air Forces lost 82 bombers over Europe, shooting down 275 enemy fighters with 84 probables, and 178 severely damaged.

U.S. armament experts were quick to reply to the new German tactics. They gave the Fortress an extra turret with two 50-calibre guns in the nose just below the bombardier's office, and it became a veritable flying porcupine. In addition they equipped special "Forts" as flying flak-ships, carrying no bombs, but an extra number of guns, and ammunition. These planes look just the same as the normal bombers, but when attacked they pour out a terrific weight of lead. By using them as "outriders" on daylight raids, the U.S. Army Air Forces inflicted heavy damage on the enemy fighters. Complained the German radio, "These four-engined planes look just like bombers, but they are nothing but heavily gunned fighters, with guns firing at unexpected angles."

During the month of October, 1943, U.S. Army Fortresses and Liberators shot down 372 German fighters on five missions with a loss of 80 bombers. On one of these missions 81 enemy planes were destroyed with the loss of 30 Forts.

Another German radio commentator almost wept over the radio as he explained to the German people what was happening in the air war. "The pressure of American bombers flying in formation over Germany is a serious problem for our interceptors," he said. "The massed firepower of the Fortresses keeps German fighter formations out of range. Our usual tactics were to separate one bomber from the formation, shoot it down and concentrate on another. This is no longer possible. Our fighters have an even more difficult task. They are called upon to attack a bomber formation bristling with weapons, suspended in the air like 'an armored cloud.'"

The German cries but he does something, and so over Europe in August the first rocket attacks were made on the Forts, after the fighters' attempt to drop fragmentation bombs proved a failure.

The first attacks by fighters equipped with rocket guns were hit-and-run affairs. The fighters weaved in towards the Fortresses, obtained a position above the bombers and released their projectiles. Such tactics were highly dangerous for the fighters, as the German pilots well knew.

Then came the perfected rocket-gun which enabled the German pilots to do long range sniping. This particular rocket projectile may only be the beginning of the aerial use of such a device.

Even before the war the Germans were experimenting with a rocket glider controlled by radio from its parent plane. This device has wings which unfold after its release from the firing tube, which give it the necessary lift, while radio control similar to that used by the British in their "Queen Bee" aircraft directs the flight of the projectile to its objective. These weapons may have been used against ships, according to a report from the Mediterranean, but they have not made their appearance in aerial warfare.

The answer to the rocket-gun-toting fighter is in the bigger and more heavily armored bomber and the use of more flying flak-ships or outriders to keep the fighter squadrons out of range of the bombers. The U.S.A. has already taken delivery of the B-29, a super-bomber said to carry a greater bomb load than any "existing type." (The Lancaster carries 8 tons, so the B-29 load might well be ten or fifteen tons.) Such a high load opens up the possibility of the conversion of some of these super-bombers into flying battleships, equipped with heavy calibre as well as 50-calibre guns and capable of carrying several tons of ammunition.

This new bomber is a pattern for the decisive battle in the air which must come before Germany and Japan crumple to defeat. The new bomber is likely to be more heavily armored than any previous model, and is certain to contain a number of power controlled turrets fitted with the

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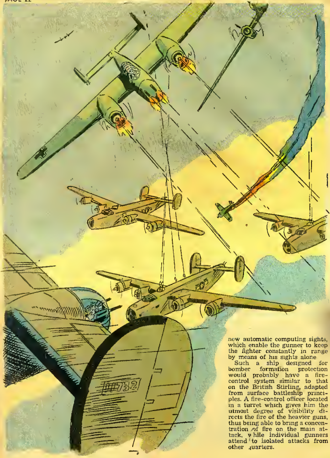
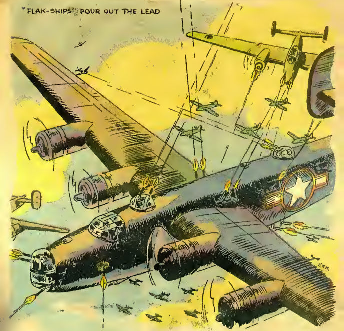


new automatic computing sights, which enable the gunner to keep the fighter constantly in range by means of his sights alone

Such a ship designed for bomber formation protection would probably have a fire-control system similar to that on the British Stirling, adapted from surface battleship principles. A fire-control officer located in a turret which gives him the utmost degree of visibility directs the fire of the heavier guns, thus being able to bring a concentration of fire on the main attack, while individual gunners attend to isolated attacks from other quarters.



In Liberators and Fortresses the turret gunner usually acts as fire control officer. Each member of the crew is in telephonic communication. When enemy planes are sighted the gunners report thus:

"German pursuit approaching at 4 o'clock. Watch him, Ed. (Ed is the starboard waist gunner.)

Ed: I'm watching. Can't see him.

Turret Gunner: He's coming in now. He's weaving. You'll see him.

Tail Gunner to Pilot: "Lieutenant, will you skid the tail, I think I could get him. (Skidding the tail will enable the tail gunner to get quick view of approaching fighter which is coming in on the waist gunner's blind spot.)

Turret Gunner: There's another fighter at eight o'clock two "angels" (two thousand feet) I'll take him.

"We're all of us on our toes," said a gunner describing his experiences. "If the Heinie gets in close, he's very lucky. Sometimes he does, usually he doesn't."

The new battleships of the air will improve on that system with the fire-control officer directing his guns. The gunners themselves, in heavily armored positions with ammunition supplied on conveyor belts, will be given range and direction and fight their ship just as does the crew of the surface vessel. Such ships will render the super-bomber formation almost impregnable except to attack from similar battleships of the air which the enemy is certain to produce, if he is to go down fighting.

Picture a formation of super-bombers going to attack a target deep in the heart of Germany. The main formation, say a hundred bombers each carrying ten tons of bombs plus fifteen 50 calibre guns, flies in wedge or stagger formation, each machine at a slightly different altitude to

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its neighbor, to avoid anti-aircraft fire—but each machine is near enough to the other to give fire support if attacked.

The rear formation (the Purple Heart element, as our fliers call it now, because it takes most of the punishment) is, as usual, an integral part of the formation, but the tail-end Charley is carrying nothing but guns and ammunition and a specially trained gun crew. It is protected by augmented armor, its fitting made possible by the elimination of bomb load. This "tail-end Charley" has a formidable arrangement of guns, with a 2000 yard effective range.

If all goes according to plan, however, it may not be called into action, for 1000 yards behind, on either flank, and ahead of the main formation are the escorting aerial battleships, equipped with heavy-calibre shell firing guns, rocket guns as protection against ships of its own type, and power turrets of fifty calibres. Before getting within range of the main formation, the enemy will have to deal with these convoy "cruisers," each capable of taking on a squadron of fighter planes, and each so placed in formation as to be able to support its mates with the full weight of its fire power.

Such formations will present the Axis defenders with a formidable problem. They will enable our Air Forces to carry even heavier weights of bombs over enemy territory with fewer losses of bombers. The Germans are probably preparing their answer to the armored fleets. These might well be "battleship" versions of the HE 177.

The Germans must have given serious thought to the question of using heavy bombers as interceptors. On several occasions they have used salvaged Forts to attack our bomber formations on daylight raids. The Dornier 217E, originally designed as a superbomber, is now the most popular night flying interceptor in the skies over Berlin. More significant still, they have armored and armed the FW Kurrier, the four-engined giant formerly used to prey on shipping in the Atlantic. Previously these big planes, originally designed as air liners, were

easy victims for Spitfires and Hurricane Catafighters, and always avoided battle. From the Atlantic front now comes news that the Kurriers are heavily armed, and ready to fight.

A U.S. Liberator on submarine patrol was attacked by two Kurriers. After a battle lasting nearly half an hour, one of the German four-engined giants was shot down in flames, the other crashed into the sea. The gallant Liberator with most of its crew wounded later made a forced landing. It had beaten its two enemies by superior gun fire and pilotage.

When the full story of that battle is told it will rank as an epic. It is also a shadow of things to come, the battles of big aerial battleships slugging it out with heavyweight punches. As a sign of the times, it is significant, it shows the Germans are impressed by the fighting power of our Forts, and are trying to emulate it. Any day now they may draw a surprise from their hat—aerial battleships with long range guns to smash up our bomber formations.

The HE 177 with its four engines in arrangement in two pairs, operating a single air screw in tandem is the only machine with which Germany can answer the Fortress. The HE 177 is a mystery ship, originally designed for the onslaught on Britain. It does not seem to have been much in evidence, but it is known to have a total hp exceeding 4,500, and to have a 7000 mile range with a considerable bomb load. It has cannon in the nose and tail and bristles with machine guns. Its speed should be in the neighborhood of 300 mph.

Such a ship with special modifications might well be used by the Luftwaffe to challenge the formations of super bombers and escorting "flak" ships the Allies will send over German skies in 1943. An onslaught by these heavily armored and armed ships could well penetrate the outflanking squadrons and reach the main section of bombers, or could engage the escorting machines to enable the fighters to bring their rocket projectiles within range of the bombers.

A defending air force always has the advantage of being able to use heavily armed interceptors with limited range, while the attacking force is deprived of the benefits of single-engined fighter escort if the target is a considerable distance from the attackers' home base.

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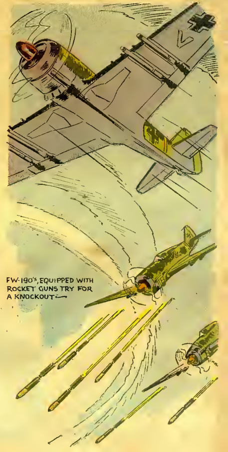


General Arnold, Commanding General of our U.S. Army Air Forces, whose wise generalship has been an outstanding feature of American use of air power, firmly believes that the bomber will end the war. He has frequently referred to the U.S. super-bombers that will deal decisive blows to Germany and Japan.

The introduction of these monsters indicates that aerial warfare is taking on the same pattern as sea and land fighting. The modern bomber is equivalent to the battleship, which must rely on light cruisers and destroyers. The bomber has the advantage over the battleship in that it has a far greater range over land as well as sea.

While battleship can destroy battleship by gunfire, it can itself be destroyed by lighter craft using torpedoes, so it employs its own screen of light craft to keep these enemies at bay. The heavy bomber has to employ similar tactics. Give it adequate protection and its crew can concentrate on the task of bomb dropping, but if disturbed it must be able to fight to protect itself, and if necessary, like the battleship, it must be able to destroy its own kind by gunfire.

The first stage of the bomber-fighter war is nearly over. The single seater fighter will give way to the heavy patrolling cruiser, and clashes between these heavies will become a regular feature of the war.

In a recent speech General Arnold mentioned that the U.S. has many new gadgets to use against Germany. What they are is a secret, but there are indications from all fronts that the policy of military aeronautics is to make everything that flies *fight*.

Just as the airplane that cannot take as much as it can give is demoded as a combat weapon, so the weapons that cannot be moved swiftly from place to place are demoded. People who know are now talking of a heavily armored plane carrying heavy calibre guns and ammunition. Its function is to fly low over enemy fortifications, land behind the lines, and act as a tank or pillbox, being able to defend itself until support arrives.

Another possible weapon is a radio-controlled plane that will fly into the middle of bomber formations and destroy them by collision. This is not a pipe-smoker's dream, either. The British for a long time have used radio-controlled light planes for gunnery experiments—and with great success.

1944 may see the strangest events in the air, such as H. G. Wells outlined in his "SHAPE OF THINGS TO COME." Great squadrons of aerial battleships may maneuver for position and bombard each other with guns of a calibre undreamt of for aerial warfare at the outbreak of the war. In their wake will come the bombers each carrying 15 or 20 tons of bombs, and escorted by patrolling flying "flak-ships." Aerial battles of several hours in duration may become common events, and strange "Rube Goldberg" devices of destruction will be put into action.

One aspect is in favor of the U.S.A. America pioneered in building the "Flying Fortress," the first and best long range well armored bomber. With seven years' start on the opposition, she is not likely to be outclassed by anything the enemy can produce. Germany has little experience with these heavies.

By sheer weight of metal, allied with valuable experience, and an elastic aircraft production source, we shall win these "Battles of the Biggies" if only by numerical superiority. When peace is won we should have evolved an aerial battleship capable of maintaining law and order in any part of the world.

PLOTTING THE COURSE

Air Navigation for Beginners

By COMMANDER SCOTT G. LAMB
Director of Training, Fourth Naval District, U. S. Navy

THE navigator's problem is so simple that it is very complicated. All he has to do is lay out a course; find the shortest route between the starting point and destination (or as the crow flies); and provide a ready check as to the accuracy with which he is following the track.

Direction and distance: these are his two values. But direction and distance in the air, where there are no beginnings nor endings and where the only "landmark" is a cloud that will be gone in a minute!

So we may well ask ourselves. Where would a navigator be without his instruments? Where would an airplane be without its instrument-panel? Instruments are the answer.

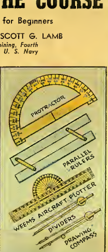
We shall discuss them.

First: the drawing compasses and dividers. The compasses are used to draw arcs and circles, dividers to measure distances and to transfer them from place to place on a map or chart. But what schoolboy who liked or disliked geometry could forget this?

Second: parallel rulers. This device consists of two rulers connected by metal strips pivoted on each end so that one ruler may be moved independently of but parallel to the other. They are used to draw lines parallel to each other at any distance apart, to measure a pre-determined course by reference to the nearest compass rose, and to lay off courses and directions. (A compass rose is a compass card printed on all navigational charts, giving true and magnetic directions.)

The protractor is an instrument for laying off angular measure on a chart and for drawing courses and directions as well as for measuring them. In its usual form it consists of either a half circle, or a full circle, of transparent material, graduated in degrees on its circumference.

One of the most useful of all instruments to the aircraft pilot is the Weems Aircraft Plotter, which combines the functions of parallel rulers, protractor, dividers and measuring scale. It is simple to use, light in weight, and replaces the other instruments mentioned.



NAVIGATION INSTRUMENTS

The magnetic compass is the most important of all instruments to the navigator, because to get from place to place on the earth's surface he must be able to steer in any true geographical direction, and to measure angles in a horizontal plane made by any visible object with his meridian. The operation of the magnetic compass is dependent on two factors:

(1) That a magnetic field exists in the space surrounding a magnet and

(2) That like magnetic poles repel each other and unlike poles attract.

The earth acts as a magnet having, as do all magnets, two magnetic poles of opposite polarity, and also a magnetic field, whose strength can be measured, surrounding the earth. The earth's magnetic north pole is located approximately in latitude 71° N, longitude 96° W, and its magnetic south pole approximately in latitude 73° S, longitude 156° E.

Due to the fact that the magnetic poles do not coincide with the geographic poles and also because the magnetic material of the earth is not uniform in disposition or location, the magnetic lines of its field are irregular and differ at many places from the direction of great circles passing through the magnetic poles.

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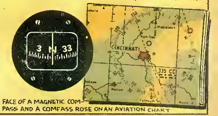
PRINCIPAL OF THE COMPASS

THE LODESTONE IS A NATURAL MAGNET

LIKE MAGNETIC POLES REPEL
UNLIKE MAGNETIC POLES ATTRACT



FACE OF A MAGNETIC COMPASS AND A COMPASS ROSE ON AN AVIATION CHART

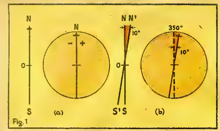


Fig. 1

If a bar or similar magnet be suspended at its balance point it will take up a general north and south direction in the plane of the lines of force of the earth's magnetic field, or, more simply, in the plane of the magnetic meridian. This, then, is the working principle of the mariner's magnetic compass. The north-seeking end of the compass points toward magnetic north, being attracted toward the magnetic north pole and the south-seeking end points toward the magnetic south pole.

The compass consists of a circular compass card carrying a group of parallel needle magnets, all with north-seeking ends pointing the same way. The card is mounted on a pivot so that it can rotate freely in a horizontal plane about the pivot. The pivot is a rigid part of the compass bowl, which in turn is rigidly attached to the plane with the pivot in the fore-and-aft center line, or in a line parallel to it. On the inner surface of the bowl and visible to the pilot, is a vertical black line, called the "lubber's line," which is also mounted in the center line forward of the compass pivot. The lubber's line is the point of reference for steering and is the mark for reading courses which show direction of the ship's head.

The angle between the geographical meridian and the magnetic meridian is termed variation and is measured in degrees. Variation, then, measures the angular distance the north-seeking end of the compass needle is deflected from true north by the earth's magnetic field. It is called East or plus (+) if the north end of the compass is deflected to the right or E (clockwise); West or minus (—) if deflected to the left or W (counter clockwise).

Although there is no known way of shielding a compass card from the influence of a magnetic field in which it lies, it is convenient for purposes of illustration to assume that this can be done, and in Figure 1 (a) this has been done.

In (a) N-S is the true meridian and a compass at point 0 would, we assume, take its position in the meridian pointing true North, or 0°.

In (b) the magnetic meridian N'S' makes an angle of 10° with the true meridian and is to the right of it. The compass now is not shielded and variation of 10° E or (+) exists, such that the 0° to the right of its position in (a), and the 350° mark of the compass card is in NS, or is read opposite the lubber's line. Variations of W or (—) would have similar effects but in the opposite (counter clockwise) or W or (—) direction.

Another error is introduced into the indication or direction of the magnetic compass card by factors within the compass itself and by local magnetism of the plane's iron and steel. These factors grouped together result in an error called deviation. This combined error is also measured in degrees and is named E or (+) W or (—), as we saw for variation, dependent on the direction in which the compass needle is deflected away from the magnetic meridian.

Deviation, however, varies in amount, dependent on the ship's head, due to the fact that the local magnetic forces within the ship differ as the ship changes direction. It is to be noted that deviation, then, is different for each course which is steered, whereas the variation for any particular locality affects all courses steered in the same amount.

In practice, to obtain deviations, the ship heads on every 15° mark by compass from 0° to 360° and deviation errors are found and tabulated for future use. This is called "swinging ship."

Figure 1 can also be used to illustrate how deviation affects the compass needle by substituting the word "deviation" for "variation" in the description of that figure.

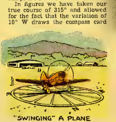
Variation and deviation are the only two factors for which the navigator corrects the compass. They are combined to form Compass Error. If both are of like sign, E or W, they are added together and then applied; if unlike, one E and one W, they are combined algebraically (the smaller subtracted from the larger) and the result is then used for correction.

Figure 2 illustrates the application of variation and deviation, assuming a variation of 10° W and a deviation of 15° E, the resultant Compass Error being 5° E.

Assume that the pilot wishes to steer a true course of 315° (or NW) from one city to another. The chart shows his average variation for the locality to be 10° W.

Figure 2 shows what his compass would read, were there no variation and deviation; in (b) the variation is introduced, drawing the compass needle 10° to the West (left) so that the compass reading opposite the lubber's line is now 325°; in (c) a deviation of 15° E is introduced, as taken from the deviation table for the magnetic heading of 325°, this serves to draw the compass needle 15° E (right) so that the compass now reads 310°.

In figures we have taken our true course of 315° and allowed for the fact that the variation of 10° W draws the compass card



"SWINGING" A PLANE

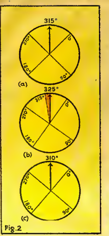


Fig.2

left to a reading of 325°; we have then allowed for the fact that a deviation of 15° E draws the magnetic reading of the card to the right to a reading of 310°. Consequently, the pilot knows that to steer a true course of 315° he should steer a compass course of 310°.

From the above we can draw a general rule for applying variation and deviation as follows:

In going from

True to Magnetic to Compass
Add W Subtract E
315° Var (+) 10° W 325° Dev (—) 15° E 310°

Reference to figure 2 will show that we reverse the process in going from

Compass to Magnetic to True
Add E Subtract W
310° Dev (+) 15° E 325° Var (—) 10° W 315°

It is to be noted that in going from compass (psc or per standard compass) to magnetic to true, deviation is applied first and then variation; in going from true to magnetic to compass, variation is applied first and then deviation.

A very convenient phrase to use as a memory aid for correcting compass readings is as follows.

Compass to Magnetic to True
Can Dead Men Vote Twice
Compass Course Deviation Magnetic Course Variation True Course
Add E Subtract W
True to Magnetic to Compass
Add W Subtract E

In all compass corrections, the student must remember that except for relatively slight deflections of the compass card, the card always points in the same direction; actually, the ship or plane moves around the compass card.

Also, in solving compass problems, if the student will consider himself to be at the center of the compass card when applying compass error, solutions will be more readily visualized.

Examples:

(1) Course p.s.c. 47°, Dev. 5° E; Var. 10° W. Required true course. 47 + 5 — 10 = 42° Ct. p.s.c.

(2) Course p.s.c. 181°; Dev. 5° E; Var. 5° E. Required true course. 181 + 5 + 5 = 191° Ct.

(3) Ct. 284°; Var 7½° W, Dev. 3° E. Required course p.s.c. 284 + 7½ — 3 = 288½° p.s.c.

(4) Ct. 90°, CE 10° W. Required course p.s.c. 90+10=100° p.s.c.

locked at any reading to correspond with the course being steered per standard compass. A pair of fixed vertical vanes is located on a ring on top of the pelorus circle, outside the dial and rotatable about the dial.

To take a bearing, the dial is locked at the heading corresponding with the course being steered and the object is sighted through the vanes. When lined up through the vanes the desired bearing is read directly from the pelorus dial.

Figure 3 illustrates the principle and gives a typical problem. In the figure, the pelorus dial is shown enlarged, set at heading of 90° with the ship's head, and the bearing taken of the external object through the sighting vanes, across the dial is 165° or 75° to the right of the ship's head. In practice, the pelorus would be located on the ship as noted in the previous paragraph.

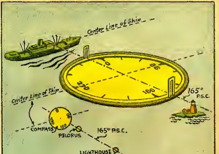


Fig. 3.

A pelorus is an instrument for taking bearings (determining the direction) of an object external to the plane for purposes of location. Usually the compass is under cover and one cannot see over it to get bearings. The pelorus is really a dumb compass mounted somewhere near the magnetic compass with its fore-and-aft line parallel to the plane's center line on which the compass is located and in such a position that one can see objects outside the ship across the pelorus dial.

The pelorus dial itself rotates in a horizontal direction, as does the compass card, and can be

From the foregoing discussion we see that there are three methods by which directions may be represented. They are:

(a) True, when they refer to directions (or angles) measured from the earth's geographical meridians, which run true north and south.

(b) Magnetic, when they refer to directions (or angles) measured from the earth's magnetic meridians which run magnetic north and south.

(c) Compass (p.s.c.), when they refer to directions (or angles) measured from the 0° or N point of the compass card.

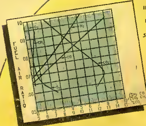


Fig 1. VARIATION OF EXHAUST GAS, IN COMPOSITION WITH VARIATION IN FUEL-AIR RATIO

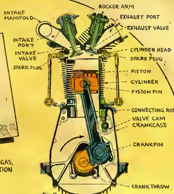


Fig 2.

HEART OF THE AIRFRAME

AN airplane without an engine? A glider—someone will say. Well, yes, of course. But surely not a real airplane, the queen of the skies we hold so high in our thoughts—not the diving, zooming craft so swift and agile in its maneuvers that it seems to be a living creature, not the powerful, heavily armored fortress of the air which serves today as a bulwark of our freedom.

No, an airplane without an engine is like a man without a heart—a dead thing, of no power, unable to work.

And so, it becomes vital indeed, for us who seek to fly a plane, to know of engines—what they are and how they give power and "life" to the airframe.

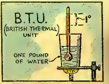
The aircraft engine and the automobile engine are brothers under the hood. That is, they are both internal combustion engines, they are both machines for turning heat energy, obtained from burning fuel, into mechanical *work*.

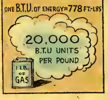
When gasoline (which has more heat energy for its weight than any other known substance) mixes with air, the result is combustion. Combustion takes place, of course, in the steam engine too. But the steam engine requires an external means, that is, a furnace, for this process. In the aircraft and automobile engine the action takes place inside the engine.

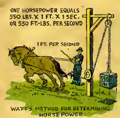
Gases, resulting from combustion, expand and push against the pistons. These in turn rotate the crankshaft by means of connecting rods.

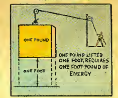
Almost all aircraft engines in operation use gasoline as a fuel. In order to understand more clearly the operation of the aircraft engine, it is necessary to learn something about the fuel which supplies the energy.

The heat energy given off by burning fuel is the measure of the work that the fuel can perform. American and British engineers use the British Thermal Unit (B.T.U.). The B.T.U. is the









heat required to raise the temperature of one pound of water 1° Fahrenheit. The number of British Thermal Units given off by one pound of fuel is used as a more convenient unit.

Modern high octane gasoline can provide 20,000 Units per pound. Twenty-one thousand units are available in a pound of diesel oil. Lower grades of gasoline drop to less than 19,000 units.

According to the engineer, *work* is done when an object is moved from one point to another. A weight of one pound lifted to a height of one foot requires one foot-pound of energy. If it is lifted ten feet then ten foot-pounds of energy are required. One British Thermal Unit of energy equals 778 foot-pounds. Thus a pound of high-test aviation gasoline can, if burned with perfect efficiency, do 778 x 20,000 or 15,560,000 foot-pounds of work. The efficiency of the aircraft engine is only between 35 and 40 per cent. So actually only a portion of the total B.T.U.'s are put to work driving the engine.

All aircraft gasoline and diesel oils are compounds of hydrogen and carbon and are therefore called hydrocarbons. The simplest gasoline is C_6H_{14} (6 parts of carbon and 14 parts of hydrogen). The carbon burns by combining with oxygen in the air to form carbon dioxide (CO_2). If there is not enough oxygen, the carbon in the gasoline is not completely burned and the highly poisonous carbon monoxide is formed. When burning, the hydrogen combines with the oxygen in the air to form water vapor (H_2O). This is found as steam in the exhaust and is readily noticed in cool weather. In improper mixtures the carbon sometimes combines with the hydrogen to form methane (CH_4) which is found in the exhaust. This is a waste since neither the carbon nor hydrogen is being burned as fuel.

Burning a gallon of gasoline requires about 1,200 cubic feet of air which gives off one gallon of water in the form of steam in the exhaust. (Fig. 1 shows the products of combustion with different fuel and air mixtures in the modern aircraft engine.)

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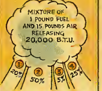
WHERE THE ENERGY IN GASOLINE GOES



1. COOLING SYSTEM- 4000 B.T.U.
2. EXHAUST LOSSES-10,000 B.T.U.
3. FRICTION-1000 B.T.U.
4. USEFUL WORK (B.H.P.) 5000 B.T.U.

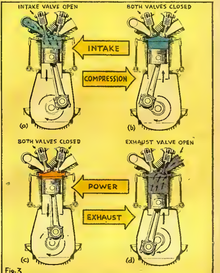


Fig. 3

Almost all aircraft engines operate on the four-stroke cycle principle. Each stroke is one vertical movement up or down of the piston (See Fig 2). Each cycle requires one revolution or two strokes of the piston, one up and one down, so that two revolutions or two cycles require four strokes. Some diesel engines and model airplane gas engines utilize the two-stroke cycle so that only two strokes or one revolution of the crankshaft are required for a complete cycle of operation.

Figure 2 shows a cross-section view of a cylinder, inside which the piston moves. The top of the cylinder (called the cylinder head) is equipped with an exhaust valve and an intake valve (Some engines have each cylinder equipped with two exhaust and two intake valves.)

The piston is fitted with a connecting rod which can pivot on the piston pin. At the other end the connecting rod is fastened to the crankshaft. The up and down movement of the piston and the attached connecting rod is converted into rotation by the action of the connecting rod pushing against the crankshaft.

One complete movement of the piston from the top of the cylinder to the lowest level is a stroke. When a piston is at its highest position in the cylinder it is said to be at top dead center (T.D.C.). When it is in the lowest position it is said to be at bottom dead center (B.D.C.).

1. Intake stroke (See Fig. 3a). The intake stroke begins with the opening of the intake valve before the end of the exhaust stroke. Thus fuel and air are entering the cylinder while exhaust gases are still going out through the exhaust valve. As the piston descends during the intake stroke, the fuel and air mixture is forced into the cylinder by atmospheric pressure, or by the supercharger. The exhaust valve closes just after the beginning of the downward movement of the piston at the start of the intake stroke. The intake valve closes after the piston has reached bottom dead center (B.D.C).

2. Compression stroke (See Fig. 3b).

The piston now moves up, from B.D.C. to the top, compressing the fuel and air mixture. Both valves are closed. The piston approaches top dead center (T.D.C.) but before it reaches it the spark ignites the fuel. The fuel continues to burn as the piston continues to compress the mixture.

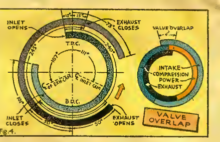


Fig. 4.

3. Power Stroke (See Fig. 3c). The fuel has already been ignited by the sparkplugs. (Two plugs per cylinder are standard on all engines of over 100 H.P. and common on most of the new lower H.P. engines.) When the piston reaches top dead center the expanding gases produced by the burning fuel force the piston down. The connecting rod transfers the motion of the piston to the crankshaft. During this period both valves remain closed until a few degrees before the end of the power stroke when the exhaust valve opens and the burning gases begin to leave. The piston continues to move down to bottom dead center (B.D.C.).

4. Exhaust stroke (See Fig. 3d). The piston now moves up, forcing burned gases out of the exhaust. Just before reaching top dead center, near the end of the exhaust stroke, the intake valve opens as previously described.

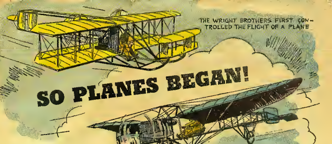
The opening of the intake or exhaust valves before or after a stroke begins is called *valve overlap*. Valve overlap permits greater efficiency and power since more fuel and air are admitted to the cylinder before the intake stroke begins. Likewise the opening of the valve permits a more rapid removal of the exhaust gases. The inertia of the gases moving out helps the fuel and air mixture to move in past the intake valve.

In the Wright J6 engine the exhaust valve opens 60° of rotation before the end of the power stroke and closes 10° after the beginning of the intake stroke. Thus fuel is admitted during 250° of rotation instead of the 180° that would be expected in one intake stroke (See Fig. 4). Valve overlap means the number of degrees of crankshaft turn during which both valves are open together. A complete revolution of the crankshaft is 360°. One-half a revolution, produced by one full stroke of the piston, is therefore 180°.

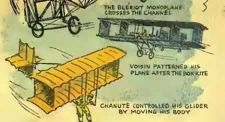
The amount of air that is moved by the piston in going from bottom dead center to top dead center is the piston displacement. In order to determine this, the bore or diameter of the cylinder and the length of the stroke must be known. The displacement is the cylinder cross-sectional area multiplied by the stroke length. Piston displacement equals $\frac{\pi\ \text{bore diameter}^2}{4}$ x length of stroke. In engines of more than one cylinder the total piston displacement is found by multiplying the above formula by the number of cylinders.

It is possible to have a volumetric efficiency greater than 100% by forcing more fuel and air into the cylinder than it can hold under normal conditions.

Valve overlap and the supercharger, by admitting and forcing in greater quantities of fuel and air, increase volumetric efficiency.



SO PLANES BEGAN!



ALREADY the history of the airplane is legendary. The Wright brothers, and those other early heroically determined experimenters—John Stringfellow, Samuel Pierpont Langley—seem figures dim as Leonardo da Vinci (who certainly experimented with the theory of flight in sketches and notes).

The history of the airplane seems legendary because, in the last three decades, it has made such startling leaps from evolutionary point to point. And when you think that, dating from that famous day at Kitty Hawk, the airplane is only 41 years old, you must admit that, for our new participant in the world scene, time has certainly been abridged.

The first recorded flight by men, not birds, goes back to the date 1783. But this flight, made by two Frenchmen, utilized the lighter-than-air theory, that is, they went up in a balloon By 1794 the French had a Balloon Corps, and Napoleon even took two balloon companies with him on the Egyptian campaign. He employed the corps for psychological rather than military reasons, however, hoping to make his opponents credit him with truly magical powers.

A balloon corps was also used in our own Civil War.

But balloons, though pretty, and useful for some purposes (especially for the collecting of scientific data about the upper regions of the air—witness Auguste Picard's highly important flights into the rarefied higher strata—53,000 feet), were too unwieldy and too subject to the caprices of atmospheric disturbances to satisfy inquisitive and perfectionist experimenters for long.

In 1804 Sir George Cayley was discovering a good deal about the glider principle and certainly proved to his own satisfaction that a simple wing attached to a stick, fitted with a rudimentary tail, would glide for quite some distance before coming to earth. But the problem of getting some means of power within the structure that would enable it to keep on going was insoluble for him.

It was not until 1848 that John Stringfellow, an Englishman, built a monoplane with an engine in it With a wing spread of ten feet, driven by a small steam engine, the plane must have looked like the proverbial bat out of hell But it did move—fly a distance of 40 yards! An accomplishment indeed, for after that, for fifty-five years, no other plane managed to get off the ground and stay off for a controlled period. Experiments were ten to the dozen and important work was done with gliders (taking off from hills, roofs, etc.), but the problem of getting an engine inside the plane that wasn't so heavy it would catapult the plane to earth or rip out the floor of the plane; the problem of devising an engine light, yet powerful—was enough to cripple the ingenuity of the most devout air-enthusiast

But there was an American! He was Samuel Pierpont Langley, of the Smithsonian Institution And by 1896, after a ten-year span of experimenting with mosquito-like little machines powered with rubber bands; after filling notebooks with data on the lift and drag of birds and of various wing forms (as Da Vinci did); after trying steam-powered models which he called "aerodromes," he too achieved what had been deemed the impossible. His "aerodrome" with a 14-foot span and a weight of 26 pounds flew over half a mile when shot into the air from the roof of a small houseboat in the Potomac River. There was, however, no one in the machine!

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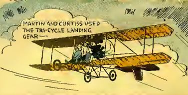
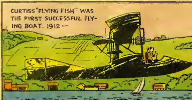




Through the influence of Theodore Roosevelt, then Secretary of the Navy, a sum of $25,000 was set aside for the construction of a plane that would manage to hold both an engine and a man

The crux of the whole problem was still the engine. Langley wanted an engine that would weigh less than 10 pounds for every horsepower. Everyone said the usual thing: it couldn't be done. But Langley's assistant, Charles M. Manley, proved that it could be done. He built a 5 cylinder radial engine with a horsepower of over 50. The total weight was well under 150 pounds.

The engine was ready. So were the men. But men and engine together? Can you imagine teaching yourself to fly the minute you are in the air? Langley's machine was not successful. Twice it was launched and twice it crashed. Congress, which had once approved the subsidizing of Langley's experiment, now heaped the courageous pioneer inventor with abuse.

But in the same year that Langley tried to fly and failed, the Wright brothers flew and succeeded

They started with kites. Then they graduated to gliders, spending two summers at Kitty Hawk, North Carolina, where winds were calm and reliable Otto Lilienthal, the German, was the first to make a thoroughly scientific approach to the problems of gliding. When he was killed in 1896, the Wrights decided that control in flight could never be dependent on shifting of the pilot's weight, as Lilienthal had thought. They decided that lateral control was a matter of the wing warping or twisting.

The Wrights also had "engine trouble" and finally, like Langley, had to commission a machinist to build an engine for them No automobile manufacturer would stoop to the job' Their machinist, Charley Taylor, turned out an engine weighing just under 200 pounds. Temporary horsepower was 12 with a momentary horsepower at 16.

In December, 1903, their airplane worked It flew. And the long experience which the brothers had had with gliders enabled them to know the feel of flight, to know, in some measure, what to expect, an advantage Langley and his co-assistant Manley did not have.

After that first brilliant test flight it was not all smooth sailing for the Wright brothers but by 1904 and 1905 they were flying in circles and making figure eights when experimenters in other countries were still barely managing to make straight line attempts.

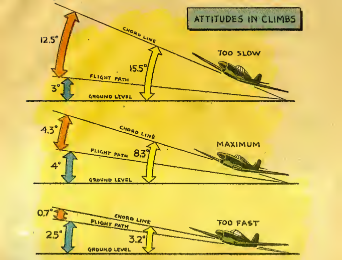
The French were far more interested in the Wrights' success than the U.S. War Department, but after 1907, when Wilbur Wright took his plane to Europe and attained the admiration of all for his machine and his flying skill, the War Department made its first advertisement for—a flying machine that would go 36 miles an hour, stay in the air for one hour minimum with two people and carry enough fuel for a flight of 125 miles. The *Wright Flyer* was only one out of twenty to be presented for Government test. For landing it had a pair of sled-like runners and was designed to be launched from a small dolly running along a single-rail track. The Flyer did well in its preliminary tests but dove one morning into the ground, injuring Orville Wright badly and killing Lieutenant Thomas Selfridge, who was with him as an observer The next year the Wrights managed to sell the Government on a new model and our United States became the first world power to own a military airplane!

But skepticism about man's new way for soaring into experience, skepticism remained dominant in the minds of Congress and the Army. Little commereial or military value was seen in the big but frail air-bug.

By 1913 the United States was spending about $125,000 a year for its step-child, aviation For the period from 1909 to 1913 England spent three million dollars, Italy nine million, Russia twelve million, France about twenty five million and Germany thirty-two million. The United States spent about half a million

But it must be remembered that the career of aviation in 1913 was a hazardous one. Misanthropes were apt to call it a sure-death one. Training airplanes at the few flying schools around the country were "old hat" models, some of them little death traps Flying technique had not been formalized; methods were still hit and guess Pilots really had to fly by the seat of their pants. But no wonder! They simply sat out in the open on seats fastened to the leading edge of the lower wing! In 1913 the various flying schools were consolidated at a single training base on North Island off San Diego, but this did not help matters. By the midsummer of 1914, eight of the Army's fourteen licensed pilots had been killed

No doubt the Government thought itself justified in keeping its aeronautical expenditures at starvation rates.



ONWARD AND UPWARD

TO CLIMB into the sky! This has been the dream of men since history began; and since the airplane is the realization of this dream, it is no wonder that *the climb* is one of the most basic maneuvers a pilot must learn.

The climb, as you know, is the maneuver by which your plane gains altitude. There are several kinds of climb. The most important are the *normal climb*, the *maximum climb* and the *steepest climb*. Now what are these, you will ask, and which is the best?

The normal climb is one at cruising air speed and with an engine speed specified by the instructor or the engine manufacturer. The maximum climb and the steepest climb are very much alike. You would think at first that the steepest climb would be the one in which you would gain the most altitude in a given time. But, as you know from experience in automobiles, a steep climb is a slow one. By dropping the nose just a little from the altitude for steepest climb we do not reduce the angle of climb appreciably, but we gain some speed. So, although the difference is slight, the maximum climb, that which gains the most altitude in a given time, is not identical with the steepest.

In practice, the steepest climb is rarely used. It is not used, as you might think it would be, for clearing obstacles as you leave an airport because at low altitudes the low speed of the steepest climb is not safe for meeting gusts of wind, downdrafts over trees, etc. If your engine failed, it would take quick work to get the nose down from the steepest climb before the plane stalled.

The maximum climb is better than the steepest, but not always the best. The pilot must be sure to maintain sufficient air flow through the cowling and around the cylinders to give adequate cooling.

Too steep a climb reduces the flow so that the cylinders become overheated. This weakens the

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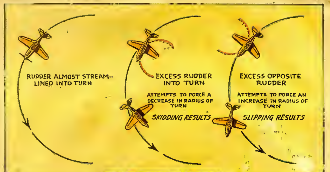


THE EFFECTS OF RUDDER

metal considerably. *Detonation*, or explosion of fuel results, seriously overstressing cylinders and crankshaft. This leads ultimately to structural failure of the engine. You should, therefore, avoid running at full throttle for longer than necessary, to insure against this.

To put your ship in a normal climb from cruising speed, apply slight backward pressure on the stick until the nose rises above the horizon to the necessary extent. At the same time, ease the throttle open to produce the desired revolutions per minute. Increased pressure must be applied to the right rudder pedal, the amount depending upon the steepness of the climb. Maximum climb is made at full throttle and at the angle and speed which result in the greatest gain of altitude in feet per minute.

You recover from a climb by merely easing the stick back to neutral and closing the throttle until the tachometer shows cruising revolutions per minute.

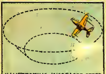
You should avoid, in climbs, applying back pressure too quickly. This puts the ship into too steep a climb. Do not release pressure too quickly, for this causes an unpleasant sensation of being raised from the seat. Try to use the rudder pedals properly. Inexperienced pilots often apply too little pressure on one pedal, which causes the ship to *yaw*, or swing to one side.

Climbing turns are normal turns made while the ship is gaining altitude. To make them, first ease the ship into a gentle climb, well below the maximum. After the climb is definitely established, make a normal turn with a bank of 30° or less, maintaining the climbing position of the nose on the horizon. You should make the turn through a definite number of degrees, preferably 180°. When you are a more experienced pilot you will make steeper banks. The various combinations of steeper or shallower turns with steeper or shallower banks are mastered as one becomes an experienced pilot.

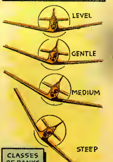
The usual rules for turns are in force. As to ailerons, use just enough sidewise pressure on the stick to control the bank as desired. Regarding the rudder, do not skid or slip; "ride with the ship" and use just enough rudder pressure so that you always feel vertical. As to the elevators, use just enough back pressure on the stick to keep the nose the proper distance above the horizon.

Recover as from a normal turn, but maintain a continuous back pressure on the stick to keep the ship climbing. After the wings are leveled, the stick may be eased forward to neutral, and straight and level flight resumed.

Skids, dangerous in any maneuver, are most so in this. They may result in a spin.



ILLUSTRATING INCREASED SPEED OF OUTER WING TIP IN A TURN



CLASSES OF BANKS

INTRODUCTION TO AERODYNAMICS

By LIEUTENANT ALEXANDER JOSEPH
Instructor of Aeronautics, U. S. Army Air Corps
Co-author of "Science of Pre-Flight Aeronautics"

OF COURSE, we want to come down to rock-bottom facts. We are interested in aerodynamics because it helps us understand how a plane can fly. We have become acquainted with this thing called lift—but what we want to know is how it operates, how it helps the plane to fly.

What happens to the plane in the air because of lift? What happens to the lift force as we fly the plane at different speeds and in different directions? What can we do, in flying the plane, in order to cooperate with the lift force and counteract drag? To find out about all this, we'll have to investigate the factors which affect lift.

In actual flight, lift may be affected by many conditions that the wing might not meet in a wind tunnel.

In level flight, if the lift becomes even slightly greater than the weight, the airplane will rise. Similarly, in level flight, if the lift becomes slightly less than the weight, the plane will descend. In either case, the flight will not be level.

For level flight, it is assumed that weight equals lift. Therefore, the lift formula can be written as a weight formula:

$$\text{Lift} = C_L \tfrac{d}{2} SV^2$$

becomes

$$\text{Weight} = C_L \tfrac{d}{2} SV^2$$

d = density of air
S = wing area
C = lift coefficient
V = velocity (airspeed)

For a given airplane, the wing area S does not change. If we assume standard sea-level condition, then d does not change. The equation tells us that half the product of these two constants, multiplied by the lift coefficient, and by the velocity squared, equals the weight. If the lift coefficient is small, the velocity squared must be large in order that the product will equal the weight. If the lift coefficient is large, and the lift is to remain equal to the weight, the velocity must be small.

$$\underset{\text{(const.)}}{W} = \underset{\text{(small)}}{C_L} \times \underset{\text{(const.)}}{\tfrac{d}{2} S} \times \underset{\text{(large)}}{V^2}$$

$$\underset{\text{(const.)}}{W} = \underset{\text{(large)}}{C_L} \times \underset{\text{(const.)}}{\tfrac{d}{2} S} \times \underset{\text{(small)}}{V^2}$$

Now we have seen in previous articles that at a low angle of attack C_L is small; hence the airspeed (V) must be large at low angles of attack. At high angles of attack, C_L is large; hence the airspeed must be low at high angles of attack. In fact, since the product C_LV^2 must be constant, for each value of C_L (i.e., for each angle), there can be only one value for the airspeed V; and for each value of V there can be only one value of C_L (i.e. only one angle of attack).

Starting, the characteristic graph curve for lift coefficients (C_L) against the angle of attack slopes upward and to the right from the point where the coefficient of lift $C_L = 0$ up to 15° or 16° angle of attack.

Starting from small angles of attack, the lift coefficient increases as the angle of attack increases. As the angle of attack increases, an angle is reached at which the lift coefficient has its greatest value. Passing this angle of attack brings us to the stalling point.

This angle of maximum lift coefficient is called also the "stalling angle." At angles greater than the angle of maximum lift coefficient, the lift coefficient decreases rapidly.

For each angle of attack, there is a corresponding airspeed, for a given weight and wing area. As the angle of attack increases, the airspeed decreases. The least airspeed is only possible when flying at the angle of maximum lift coefficient. Another name for this angle of maximum lift efficient is, therefore, the *angle of minimum speed*.

When weight is added to an airplane, the wing loading (ratio of weight of airplane to the wing area) is increased (Fig. 25). In order that the airplane may continue to fly at the same angle of attack as before, the airspeed must be increased. This is true for all angles of attack up to the maximum; hence, the greater the load, the greater the landing speed.

"Clipping the wings" is some-

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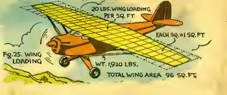


Fig. 25. WING LOADING

times done to increase the speed of airplanes for racing or other purposes. This decrease in wing area means an increased wing loading and a higher landing speed A higher velocity is then required for any one angle of attack, compared with the wing area before it was reduced. In warfare, bullet holes in the wing will similarly reduce the effective area and increase the wing loading.

In steep dives, the wing is near or at the angle of zero lift and the air is flowing smoothly over the surface of the wing. If the stick is brought back sharply, the inertia of the plane carries it along its steep-dive path for a brief instant until the reaction of the tail surfaces begins to pull the airplane on to a new path. For a tiny fraction of a second, while the wing is at this large angle of attack, the airflow follows the surface of the wing. At this moment, the value of C_L is very high. Almost immediately, however, the flow breaks away. As the new flight path is taken, the angle of attack becomes more nearly normal.

With the wing loading unchanged, for the same angle of attack, a decreased air density means that an increased airspeed is necessary to maintain the same lift If you are at sea level, where the air is densest, a certain velocity corresponds to a given angle of attack. If you are at a higher altitude, where the air density is less, the plane must be flown faster to maintain the same lift (Fig. 26b).

The landing speed also increases with altitude, because of the reduced air density. Consequently, when an airplane is landing on plateaus or on lakes in mountain ranges, it must land faster to maintain lift. (See Fig. 26). On warm days, air density is less than on cold days. On damp days, air density is less than on dry days, since water vapor is lighter than air. On a warm day, with high humidity, the take-off speed and the landing speed must be higher than usual.

Now we want to know a little more about drag—that force which retards the forward motion of the wing The total drag (or resistance of an airplane to the airflow) is usually considered as composed of two main parts called "wing drag" and "parasite drag."

The wing drag is that portion of the total drag which is contributed by the lifting surfaces (or airfoil) and is itself composed of several parts

The parasite drag (see Fig. 27) refers to the resistance of those parts of the plane which do not contribute to lift, such as the fuselage, landing gear, struts, vertical and horizontal tail surfaces. This parasite drag is due to two forces: a) the positive pressure acting to retard the movement of the surfaces and b) the friction of the air as it passes over the surfaces of these parts. The latter is known as *skin friction*. (Figs. 28 and 29) In airliners, the skin is waxed frequently to reduce this skin friction.

Both parasite drag and wing drag vary approximately as the square of the velocity. *It is the function of the propeller to furnish a forward-acting force or thrust to balance the backward-acting force of drag.*

If an unbalanced force (that is, one not counteracted by an equal force in the opposite direction) acts upon a body, it produces an acceleration (change in

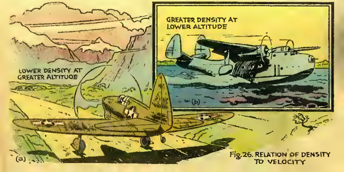


Fig. 26. RELATION OF DENSITY TO VELOCITY

Fig 27.

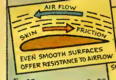


Fig. 28

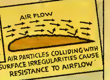


Fig. 29.

speed or change in direction or both) and this acceleration over an interval of time means a change in velocity

If a body is observed to be moving with constant velocity, that is a positive indication that there are no unbalanced forces acting on it Now, if an airplane is in motion at a certain speed (see Fig. 30) and the forward-acting force of thrust is just equal to the backward-acting force of the total drag, (wing drag plus parasite drag), then there will be no acceleration and the velocity will remain constant.

If the thrust is increased, as in Fig. 30 (2), so that it is greater than the drag, there will be an unbalanced forward force The drag will balance or counteract only part of the thrust, and the excess thrust will cause a forward acceleration and hence increase in velocity. As velocity increases, the drag increases since drag varies as the square of the velocity. As soon as the drag has increased till its force is equal to the thrust, there will be a balance, and with balanced forces, there can be no acceleration.

If the thrust is decreased so that the drag is greater than the thrust, there will be an unbalanced backward force as in Fig 30 (3) This will slow down the airplane, decreasing the velocity and causing a decrease in the drag. When the drag force has decreased until it is equal to the lesser thrust force, once more there is a balance of forces, so the airplane continues to move forward at the reduced speed

If we consider the wing alone, the drag varies not only with velocity squared, but with the angle of attack. In all flight the proper airspeed is connected with the angle of attack, since with small angles the velocity must be high and with large angles the velocity is low For level flight, the lift (L) is equal to the weight (W), so that from a curve of drag over lift D/L values may be read and, as is shown in the equation below, multiplied by the constant value of the weight, giving us the drag

$$\frac{D}{L} \times W = \frac{W}{D} \times W = D$$

Let us suppose that a plane is flying at a certain angle of attack at sea level. The pilot takes the plane up several thousand feet and flies along at the new altitude, maintaining the same angle of attack as before. How does this affect the drag?

Since the air density is lower at the higher altitude, it becomes necessary to fly the plane faster in order to maintain the same lift as before. Now, we have seen that the total drag is given by the formula:

$$D = C_D \frac{d}{2} SV^2$$

The wing area S, of course, remains fixed Furthermore, the value of C_D is the same, both at sea level and at the higher altitude, for we are maintaining the same angle of attack in both situations Hence the drag now depends only on the product of the density and the velocity squared

But in the equation $W = C_L \frac{d}{2} SV^2$ the weight W and the wing area S are fixed and the value of C_L is also constant, because the same angle of attack is being maintained. Hence, the product dV^2 must remain constant In other words, the decrease in the value of d is exactly neutralized by the increase in V^2. Now we have shown that drag D depends only on the product dV^2 and we have also shown that dV^2 remains constant Hence, drag, whose value depends on dV^2, must also remain constant in this situation

Thus, for a given airplane, the drag in level flight does not vary with altitude, but depends only on the angle of attack If the drag is known at one altitude, it will be exactly the same at any other altitude, providing the angle of attack is unchanged.

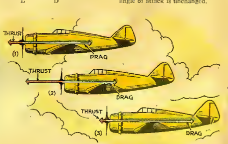
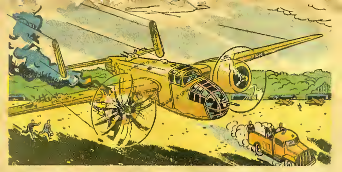


Fig.30. RELATIONSHIP OF THRUST AND DRAG



TACHOMETERS

A TACHOMETER is, in a sense, the timepiece of the engine; that is, it indicates the number of revolutions per minute of the engine crankshaft and, like a good clock, must be kept with care.

But more, the tachometer keeps the pilot informed about the "health" of the aircraft engine. As soon as anything in that minutely adjusted mechanism goes wrong, it reports the fact on its calibrated black face.

For example, if reduced R.P.M. occurs (without, of course, a change in throttle setting), the tachometer signals such loss of power. Or if the engine, just before take-off, fails to reach its rated R.P.M. (when the throttle is wide open and the brakes are locked), the tachometer will also advise of that trouble just as a good clock will report the correct time, when one is late, no matter how desperately one wants the clock to be wrong!

Moreover, the tachometer is of indispensable aid to the pilot whose concern it is to keep his engine in apple-pie order and to operate it as economically and efficiently as he can. It indicates at what R.P.M. figure fuel consumption is lowest and thus the pilot is able to adjust the throttle setting so that engine speed may be held at its most economical level.

How is the tachometer able to record so directly the power output of the engine? There are three types of tachometer. (1) Centrifugal (mechanical) (2) Magnetic (3) Electric.

In the *centrifugal* tachometer, a flexible cable transmits rotations of the engine shaft to the drive shaft of the tachometer. The instrument, in a highly intricate way, converts rotation of its drive shaft into a pointer reading of R.P.M. Different tachometers have different ranges of R.P.M. indications. A common range is from 500 to 3500 R.P.M.

For a light airplane with fixed-pitch propellers, the tachometer gives a direct reading of R.P.M. If the aircraft engine is equipped with a supercharger and operates either controllable-pitch or constant-speed propellers, the tachometer indication is combined with manifold pressure and propeller pitch to arrive at the proper reading. A careful fellow, the tachometer!

What does the tachometer look like behind its face? How do its parts move? How many units are there, working together so neatly and intricately?

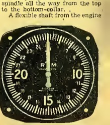
Read, and you shall see.

The centrifugal tachometer consists essentially of a governor assembly and a linkage system, the latter converts the measuring-motions of the governor to a pointer indication. All the units are contained in the instrument case, as is also the graduated dial —around which the pointer sweeps, giving the desired R.P.M. indications.

The linkage system comprises such essential parts as the governor spring, a spindle, the plunger, a ball, a jewel and the pushrod. Other elements in this mechanism are the pusher-arm, a rocking-shaft, the sector, a pinion, and the tapered handstaff to which is attached the pointer.

The governor is a whirling weight assembly comprised principally of three weights connected by links to a fixed top-collar and to a sliding bottom-collar. There are three sets of such links, one set for each weight. Each link is pivoted at both ends, allowing it to change its angular relation to both weight and collar. A governor spring winds around the spindle all the way from the top to the bottom-collar.

A flexible shaft from the engine



CENTRIFUGAL TACHOMETER

connects to the tachometer drive shaft. As the engine turns over, this flexible shaft spins the drive shaft, thus rotating the gear. This gear meshes with the spindle-pinion, turning the latter at a higher rate of speed.

The entire whirling weight assembly spins round with the spindle shaft. Centrifugal force is thus exerted upon the weights and this, naturally, causes them to fly away from the center of rotation. The faster the shafts rotate, the greater becomes the centrifugal force. So the weights fly farther and farther.

When the weights fly out, the bottom-collar slides upwards and this action squeezes the governor spring together. The distance which the spring moves, as it compresses, is a measure of engine speed.

But how is the motion of the spring converted into R.P.M. indication? Explanation must proceed!

Inside the tachometer spindle is a plunger. It is rigidly connected to the bottom-collar by a pin. Whenever the collar slides along the spindle, the plunger at the same time is pushed a corresponding distance. The ball is forced against the jewel which is set in the top of the pushrod. The pushrod is thus moved in the same direction as the plunger, pushing the arms and so rotating the rocker shaft. An arm on the rocker shaft engages the lever attached to the sector.

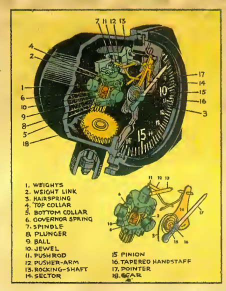
As the sector moves, the pinion, which is meshed with the sector, rotates, turning the tapered handstaff. (The handstaff, remember, is an integral part of the pinion.) As the pinion and handstaff rotate, the pointer which is attached to the handstaff deflects in a clockwise direction giving the increased R.P.M. reading.

A hairspring takes up play between the sector teeth and the pinion teeth and so contributes to smooth operation of the pointer.

As engine speed decreases, reduction in centrifugal force lessens pressure on the governor spring, and the latter forces the bottom-collar back toward the bottom of the spindle. The collar carries the plunger with it, establishing a reversal of the train of motions previously listed. This, naturally, results in a lowered R.P.M. indication.

And this ends the story of the centrifugal tachometer's workings. But—there are tachometers and tachometers, and we are not finished with the subject yet.

The second principal type of



tachometer is the magnetic tachometer. In the magnetic tachometer, the flexible shaft from the engine rotates a small permanent magnet. The poles of this magnet pass close to a metal disc or drum. This drum is free to turn against a spring. As the magnet rotates, it exerts magnetic force on the drum. This force increases with the speed of the magnet and causes the drum to take up a position which corresponds to the speed of the magnet and thus is a measure of the speed of the engine. The motion of the drum is transmitted to the indicator hand which moves over a dial showing R.P.M.

The third and most efficient type of tachometer is the electric tachometer. In the electric tachometer the output of the generator (which is mounted on the engine) is measured by a voltmeter calibrated to read in revolutions per minute. This tachometer is better adapted than the other two to the needs of a more complicated and highly developed airplane. Its great advantage is that there is no long revolving shaft, so it may be practically used when the engine is located at some distance from the cockpit.

On a four-engine bomber, one tachometer is not enough. Each engine must have its own indicator. In fact, more than four tachometers are required for four engines. For not only do the pilot and co-pilot consult the dial; the flight engineer must refer too to its readings. Therefore, the flight engineer's station must have four tachometer dials and so must the instrument panel at the pilot's station.

Now in the case of so many tachometers working so hard and fast the problem of space usage comes to the fore. Obviously, electrical wires take up less room

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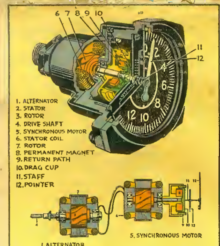

Courtesy of Bendix Aviation Corp.

than shafts. Obviously, too, it is simpler to achieve connections and inter-connections by means of electrical wiring.

Furthermore, the heavy flexible shaft found in the centrifugal and magnetic tachometer, due to its length, tends to whip and make the hand of the instrument oscillate, thus making accurate reading difficult. In the case of the electrical tachometer, the only connection between the engine and the instrument consists of two small wires.

Hence the reason for electric tachometers on multi-engined planes.

The electric tachometer is comprised, basically, of two distinctly separate units. One unit, an alternator, is mounted on the instrument panel. The panel unit incorporates a synchronous motor which receives its power and speed-controlling frequency—via electric wire connections—from the alternator. The synchronous motor, driven by the alternator, in turn motivates the tachometer indicating mechanism.

But let us get a mechanic's eye view of the electric tachometer.

First in importance is the alternator. It is comprised of stator and rotor. The unit is connected to the tachometer drive shaft of the airplane engine. As the engine turns over, the alternator drive shaft spins and with it spins the rotor. The latter rotates inside the stator coil, generating an

ELECTRIC TACHOMETER

alternating current, the frequency of which varies directly with the R.P.M. of the aircraft engine. Electric wires conduct the current so produced to the synchronous motor, mounted at the instrument panel. Consequently, this motor, which operates the R.P.M. indicator, duplicates precisely the speed of the distant alternator.

The self-starting synchronous motor also consists of a stator coil and a rotor. A small permanent magnet and its return path rotate at the same speed as the rotor.

The sole function of this whole system is to spin the magnet assembly at a speed identical with that of the engine tachometer drive. The work of the remainder of the mechanism is to convert the motion of the magnet to a pointer indication of engine R.P.M.

Among the units of the indicator mechanism is the drag cup. It is mounted on the staff. The pointer is attached to the other end of this staff. Between the pointer and the drag cup is a hairspring. Note that the drag cup wall is interposed between the magnet and the return path. There are no mechanical connections between the drag cup and the other two units.

Lines of force, comprising the flux or field of the magnet, loop from the magnet to return path, and back to the magnet—leaving the magnet at its north pole and re-entering at its south pole, thus completing a magnetic circuit. As the magnet spins, these lines of force rotate with the magnet. In so doing, they sweep through the metal walls of the drag cup. When a magnetic field moves through metal, eddy currents are induced in the metal. The eddy currents thus induced in the drag cup produce a torque, or rotative force, causing the drag cup to follow the magnet around.

The purpose of the hairspring is to resist, to a certain degree, the rotation of the drag cup. These two opposing forces are balanced in such a way as to provide a pointer deflection corresponding to the R.P.M. of the engine. The faster the aircraft engine operates, the faster the magnet spins. The intensity of the eddy currents set up in the drag cup becomes greater, and the drag cup turns with increasing force against the hairspring. This causes the hairspring to compress in a tighter spiral, thus permitting the pointer on the dial to deflect to a higher R.P.M. indication.

THIS IS THE AIR FORCES PROVING GROUND

By BRIGADIER-GENERAL GRANDISON GARDNER
Commanding General, A.A.F. Proving Ground Command

ON the ground and in the skies over Eglin Field, set down in the heart of the Choctawatchee National Forest in northwestern Florida, the Proving Ground Command of the Army Air Forces carries on its ceaseless mission, twenty-four hours each day.

Here the combat-worthiness of aircraft, accessories, equipment, and supplies is tested and evaluated. Here, the performance characteristics and the capabilities of the combat tools of the Army Air Forces are subjected to gruelling tests with the single purpose of *proving* their use for tactical purposes, and of demonstrating how they may be employed with maximum effectiveness.

That the purpose and the objectives behind the organization of the Proving Ground are being realized is already amply demonstrated in a number of vital contributions to the success of the air warfare waged by the Army Air Forces in various theatres of action. The very existence of the Proving Ground is an assurance and a concrete evidence of the determination of the Army Air Forces to equip its combat units with fighting tools that have been tested and proved worthy, and that represent the finest products of American ingenuity and manufacturing skill.

The evolution of the Proving Ground provides an interesting history in itself. The need for such an organization became plainly apparent as the nation shook off its peace-time lethargy and girded itself for defense. New designs and developments in combat aircraft began to come thick and fast. Developments in armament, in the number and type of turrets, in fire-control systems and items, in aircraft ordnance, in all manner of accessories and supplies, began to pile up.

Testing for research and experimental purposes was one matter; facilities were available and growing at the Materiel Center and in the aircraft plant laboratories. But the problem of determining objectively whether these developments met realistic

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WHAT IS THE FIREPOWER of a 37 mm. cannon? AAF Proving Ground tests must determine this. Cannon is mounted on truck for testing purposes.

METHODS OF GROUND STRAFING are practiced by an A-20 Douglas light bomber at Army Air Forces School of Applied Tactics at Orlando.

EMERGENCIES ARE EVERYDAY OCCURRENCES for these AAF boys who must test life-saving equipment. Crew of a B-17 takes to rubber boats.

GAS TESTS are highly essential. In this picture, boy takes sample of gas from his friend's oxygen mask. Another is using the Scholander tester

combat conditions and met them with maximum effectiveness was quite another and equally vital matter. Facilities for conducting such tests were scattered, unorganized, and meagre at best.

In the autumn of 1941, the Air Corps Board, an advisory body of the Chief of the Air Corps, moved to Eglin Field, Florida. The Board had as its function the making of recommendations intended to improve the Air Corps: its directive required that such recommendations be based upon the results of actual research and tests. Eglin Field, with an extensive reservation and numerous gunnery ranges, was regarded as a desirable site because it provided unusual facilities for operational tests and proving. On May 19, 1941, Eglin Field was designated as the Air Corps Proving Ground.

In July, 1941, a group, made up of fighters and bombers, was assigned to Eglin Field and activated as the Proving Ground Detachment to implement the proving missions and conduct the tests planned and coordinated by the Air Corps Board. The eventual structure of the Proving Ground then began to grow apparent.

On August 19, 1941, the Commanding General of the Army Air Forces, who had evinced the strongest personal interest in the creation of an effective Proving Ground, addressed a letter to the newly created Air Corps Proving Ground in which he stated clearly that the equipment and personnel of the Proving Ground Detachment "will be used to test air planes, equipment and new gadgets and approve their use as tactical weapons." The Proving Ground became a reality. In its initial stages, the Air Corps Board directed the planning and coordinating activities of the Proof Department. The Proving Detachment became the medium for the actual conduct of test operations.

But there were still other transitions to come, to fit the growing needs of the expanding Air Forces, to meet the great need for proving and testing the combat capabilities of the flood of new equipment coming from laboratory and factory.

In March, 1942, personnel of the Air Corps Board were absorbed in a series of organizational changes which resulted on April 1, 1942, in the activation of the Air Forces Proving Ground Command, which was made responsible directly to the Commanding General of the Army

TESTING A NEW TYPE PLANE for evacuation of the wounded. Such improvements are always worth a trial.

OFFICERS STUDY MICROFILM to obtain valuable information on living conditions in all combat zones.

Air Forces. The Proof Department was evolved into approximately its present form. The Proving Ground Detachment became the Proving Ground Group. The reservation grew and now incorporates the entire Choctawhatchee National Forest, approximately six hundred square miles in area and includes ten separate flying fields and sixty-seven distinct land and water firing ranges.

A permanent and workable organization was finally established which, save for minor changes, represents the current structure of the Air Forces Proving Ground. The Proof Department plans and sets up the test and proving programs, records the results and delivers the reports. The Proving Ground Group is the operational organization that actually executes the test projects (Proving Ground Detachments function also at the proving grounds located at Aberdeen, Maryland; Edgewood, Maryland; Hope, Arkansas; Madison, Indiana; Tooele, Utah; and Huntsville, Alabama.)

The manner in which the Proving Ground functions may best be demonstrated by examining the procedure to which a hypothetical test or proving project is subjected. Requests for test projects emanate primarily from the Commanding General of the Army Air Forces, and from the Materiel Center, Wright Field.

A typical request is made in the form of a letter outlining the test desired. The letter is accompanied by inclosures describing the equipment to be tested, outlining the purpose of the test, and itemizing the conclusions desired. The Chief of the Proof Department and his assistant review the request and evaluate it. It is then assigned to the appropriate Proof Department section. These are five in number: (1) Bombing Section; (2) Machine Gun and Cannon Section; (3) Tactical Suitability Section; (4) Radio Section; (5) Miscellaneous Section.

Once the request is in the hands of the appropriate section, a rough draft of the test program is formulated. This program is then examined in conference and amended or modified as appears desirable. When the final program is determined, it goes back

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FLIERS ARE TESTED for carbon monoxide in blood, because it causes fatigue, illness at high altitudes.

OLDEST METAL OXYGEN CHAMBER used just after World War I. What progress has been made in this field!

TESTING THE TRI-METROGON CAMERA which photographs 8000 sq. miles of terrain per hour. Photography plays a great part in this war.

THIS WAS A TRUCK before it hit a land mine! AAFSAT 4-day orientation course demonstrates the use of weapons and explosives.

to the appropriate section where it is assigned to a project officer. A program schedule is drawn up and the project officer of the Proof Department turns the actual testing assignment over to the commanding officer of the Proving Ground Group in the form of a directive.

The assignment is then turned over to a project officer (flying officer) of the Proving Ground Group who does the actual test work himself (fires the gun, flies the plane, etc) or who supervises the work personally. Installations required for the conduct of the test are provided by the Proof Department Planning and Facilities Sections. Progress reports on the project are kept.

The results of the completed test are reported in a rough draft form prepared by the responsible project officers of both the Proving Ground Group and the Proof Department. If an analytical study of the results of the test is required, involving the aid of mathematicians, physicists, or statisticians, the Analysis Branch of the Proof Department is called upon for consultation and for interpretation of the findings.

Once there is general concurrence on the results, the report is submitted to the Proving Ground Committee which consists of the Commanding General of the Proving Ground Command, the Chief of the Proof Department, the Commanding Officer of the Proving Ground Group, and Proving Ground Ordnance Officer. Here it is finally evaluated, revised and approved.

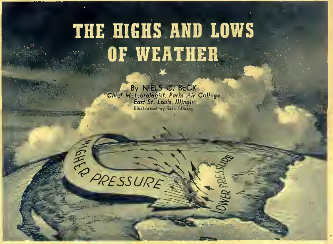
The completed version of the report is then formulated and disseminated to the organization which originated the request, as well as to other units to whom such information may prove pertinent.

These testing and proving activities have borne rich fruit. The results grow more apparent each day in the far-flung theatres of this global war.

American squadrons are waging successful war in the air not only because they have the finest training in the world and an unconquerable will to win, but also because their fighting tools have been proved as the finest and the most combat-worthy equipment this country can produce, and because they have been shown how to use those tools most tellingly. The Proving Ground will continue to insure the combat-worthiness of the weapons of the A A F by thorough testing, thoughtful evaluation and purposeful demonstration of their use.

THE HIGHS AND LOWS OF WEATHER

By NIELS C. BECK
Chief Meteorologist, Parks Air College
East St. Louis, Illinois
Illustrated by Eric Sloan



IN WINTERTIME, over a cold continental surface like Canada, weather observers would be likely to find a great mass of cold air.

This is a fact of great interest to us, if we are really going to delve into the mysteries of weather. Why is this so? How can we account for it? Here is the story.

We know that a difference in heating is the fundamental cause of pressure differences.

Research has discovered that certain portions of the earth act like radiators, or heaters, for the atmosphere, and certain parts, such as Canada, act like coolers.

Observers have noted that masses of cold air found over Canada move frequently, spreading down over the United States and out eastward toward the Atlantic Ocean; flowing like a fluid and under-running other air because they are colder and heavier. Such great cold air masses are called highs, because they are, in effect, high pressure zones where the air is heavier and denser than the air surrounding it.

As these high pressure zones pass over reporting stations, pressures are seen to increase until a maximum pressure is reached near their center. Then pressures decrease until the station may again be in a region of warmer and lighter air.

Moreover, the forward edge of these moving cold air masses is marked (as we have seen in a previous article) by weather: that is, wind, clouds, and frequently, precipitation. Observers have correlated the magnitude of this type of pressure change with the intensity of the weather disturbance that accompanies it. In general, the greater the dynamic change in pressure which is occasioned by the movement of one of these cold air masses, the more severe is the weather disturbance associated with it.

You can see now the importance of being able to extract the dynamic change in pressure from the other changes. For example, certain portions of the United States act like a battleground for enormous masses of air. Some move down from the north and others up from the south. Sometimes the cold air under-runs the warm and shoves it back in a southerly and easterly direction. Sometimes the warm air over-runs the cold and drags the forward edge of the advancing cold air backward in a northerly direction.

Suppose you had two pitchers—one filled with heavy oil and the other with molasses. You stand before a large flat-top table and hold the pitchers out at arms-length at some distance from one another and proceed to pour them on the table. (We're not particularly interested at this moment in the fact that you'd be making a pretty sticky mess of the table.) The fluids would spread out in all directions, their inner edges eventually meeting before your eyes in the center of the table. The heavier molasses would, at a point of junction, stay underneath and the lighter fluid, oil, would over-run on the top.

You could also see very graphically that, in terms of the weights of the fluids, pressure would be higher near the center

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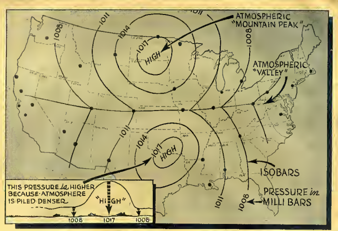


of each fluid where the pouring was taking place, and then they would meet near the center of the table in a valley-like depression, where pressures would be at a minimum.

Something very similar to this actually occurs in the atmosphere. Certain regions, north and south of what we call the mid-latitudes, act as regions in which air is accumulated. That is, air piles up, just as the fluids on the table would pile up as a result of being fed in from aloft.

When a sufficient quantity of air accumulates in one of these regions, it starts to flow out, frequently meeting another and different type of air in its journey. The strange thing (to the layman's mind) about these air masses, is that they do not mix readily as we might expect air would do. Rather, they behave just as do certain liquid fluids of different densities. The denser (colder) fluid remains on the surface and the lighter (warmer) fluid over-runs it.

In the atmosphere, these depressions or valleys that we find near the outer edges of moving high pressure air masses may also be zones of bad weather. It then becomes extremely important to locate them accurately, to determine their rate of movement and, in effect, to decide or forecast what kind of weather they will produce when they pass over a given point.

It should be apparent by this time that the dynamic, or weather, change in pressure is hidden, as a result of being part of a total pressure change in which the seasonal, the diurnal, and the altitude changes play a part.

How, then, do we arrive at the amount or magnitude of the dynamic change?

By taking all pressure reports at approximately the same time of day (and, of course, of season) the diurnal and seasonal changes are simply and effectively eliminated from the problem. (This is what we call the synoptic fashion of making weather reports.)

It is more difficult to deal with the altitude change. The fact that Denver, Colorado, reports lower pressures than St. Louis, Missouri, certainly cannot be interpreted as meaning that Denver is in a depression and St. Louis is in the center of a high. The simple fact is that the elevation of the Denver station is some 5000 feet above sea level and year-round pressures there will run lower than they do in St. Louis.

This difficulty has been somewhat obviated by a process called "correcting pressure to sea level." It is assumed that all stations reporting pressure are at a common level (called sea level) and upland stations are corrected to this level by adding an automatic correction factor.

The present method of making this correction is rather involved and not entirely satisfactory. It will not be touched on here, and it will suffice to say that in general it makes all station pressures appear as though the station were actually at sea level.

Having accounted for the three individual types of changes, the only pressure change that could now make itself evident would be the dynamic change. Therefore, the allocation of a trough or valley in the atmosphere, as distinguished from the high pressure hills surrounding it, is simply a matter of plotting the reported pressures for any given hour on a map of the United States. A line may then be drawn through stations reporting pressures which are at a minimum.

We go further with this map and draw upon it what are known

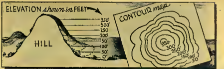
as isobars. Isobars are lines of equal pressure. In drawing, you can see how these lines of equal pressure are very similar to the contour lines of constant elevation on a geography map. That is, the isobar is a device for illustrating the topography of the atmosphere.

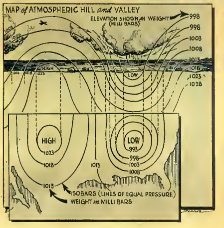
Observers at weather reporting stations report their pressures in terms of a pressure unit known as a millibar. In effect, the number of millibars expressed is simply a means of indicating the weight, and therefore the height of the atmosphere over a given station. A more detailed discussion of the unit is not essential here. It should be obvious that a pressure of a thousand millibars is higher than one of nine hundred millibars.

In the drawing the high pressure air mass lying over the Canadian border has a central closed isobar labelled 1017 millibars—which means simply that all pressures within this isobar are 1017 millibars or more. Outside that is another closed isobar labelled 1014 millibars, which means that all station pressures between this isobar and the inner isobar range between 1014 and 1017 millibars. This is very similar to a statement regarding elevation on an ordinary geographical map, whereby we might say that the central 1017 isobar marked the top of a hill and within it all terrain was a thousand feet in elevation or higher. The next isobar might be likened to a lower elevation contour line and so on. If weather maps were colored in gradient tints, as our aviation strip-maps are, to show elevations, a "high" would be brown (like a mountain peak) and a "low" would be green (like a valley). Although we cannot see it, the topography of the atmosphere is a maze of surging mountains and seething sink holes passing above us.

So, in short, whenever you wish to know the average pressure of any portion of the atmospheric terrain, it is only necessary to look at the isobars that bound it—for its pressure must range somewhere between these two values.

A cross-sectional view of a weather map, as in Figure 2, shows the presence of isobars in a vertical plane. Air which, like water, is a fluid and is affected by gravity, flows around these atmospheric mountains, falling away from the "highs" and emptying into the "low" valleys. Note then that pressures decrease, not only as we move out from the center of a high, but also as we move up from the center.





Take a pencil and draw a line out from the center of the high pressure cell illustrated. You will find that you are crossing lines of lower and lower pressure. Then take your pencil and draw a line up from the center, and again you will see that you are crossing lines of lower and lower pressure.

This is exactly what does occur in the atmosphere within one of these high pressure centers—and this change in pressure is referred to as a gradient. We may speak of a horizontal pressure gradient and a vertical pressure gradient, meaning the rate of decrease in pressure along a horizontal surface or the rate of decrease in pressure as we ascend along a vertical line.

The spacing of the isobars is also important, for it tells the approximate difference in pressure between two points. If the isobars are close together, then pressure is changing rapidly and the push creating wind will be large. If they are far apart the pressure force causing winds will be small.

In terms of what we have called pressure gradient, the gradient in the first case will be steep and in the second shallow. Practically speaking, this all means that in any pressure field where the isobars are close together, winds will be strong, and in any pressure field where they are far apart, they will be weak. In general, since the spacing of isobars in lows is usually much closer than in highs, the wind velocities in lows will be greater than in highs

CAP CADET SCHOOL

New CAP Project is a Splendid Community Experiment Offering Free Courses in Fundamental Aeronautics

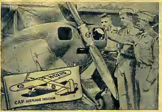
THE ONCE large and proud Civil Air Patrol Squadron at Orlando, Florida, was almost decimated.

For months the Squadron, officially known as 414-1, had been recognized as one of the largest and finest in the South. Air-minded citizens of the progressive city of 52,000 had formerly vied with one another to become members of the elite organization.

The war had made its demands upon the personnel of the Squadron. Between the squeeze of the draft, voluntary enlistment in the armed services, and the need for CAP members on anti-submarine patrol, there seemed little hope for continuing the Squadron. It is no wonder the remaining members sat around glumly one night last December in the municipal airport office. Ideas were suggested, only to fall flat.

Perhaps a pinch of necessity seasoned with some downright hard thinking is required to produce a really good idea. No one knew exactly who originated this one. But before the meeting had ended, members were excitedly discussing the prospects of forming a Civil Air Patrol Cadet School at Orlando.

"Fellows, it's the only way we can continue to justify our existence as a patrol. We've got to teach 14-17 year-old boys and girls the fundamentals of aviation. Regardless of whether they go into civil or military aviation, or whether they become CAP members, a school teaching such



ENGINE PERFORMANCE of Luscombe 8-A explained to two Cadets by CAP Training and Operations Officer.

PRACTICAL INSTRUCTION is offered to serious boys and girls in CAP airplane mechanics classes.

fundamentals will enable them to help themselves in the world of aviation when the war is over," Commander J. B. Dyer told his Squadron members.

The entire CAP membership endorsed the idea that night.

Lt Don Stremmel, operations and training officer, and local manager of National Airlines at Orlando, together with several other members, were charged with working out a detailed program. The curriculum of the proposed school not only had to be appealing to the Cadets, but had to be carried on with little or no expense. The Squadron's funds amounted to less than $100.

The committee headed by Stremmel first developed a theoretical program on paper for a group of 50 high school girls and boys in the 14-17 age group. It was the concensus of the patrol that the Cadet School would be lucky if they obtained 50 Cadets who would follow a program to completion

A six months period of instruction was worked out. About 20 regular CAP subjects already familiar to CAP members were to be studied at the start of the program They included military courtesy and discipline, civilian defense regulations, first aid, interior guard duty, defense against gas, airplane and engine mechanics, and organization of the Army, Navy, and Army Air Forces.

Later, when the students had advanced far enough, it was planned to offer air navigation, Morse Code, meteorology, parachutes, care and use of firearms, jiu jitsu, theory of flight, and civil air regulations.

Members were hopeful that if instructors and facilities could be made available, students would also receive primary and basic flight training, Link trainer instruction, and possibly advanced flight training.

The Cadet School was divided into four semesters of six weeks each; two nights weekly and two hours each night. Thus each semester provided 24 hours of intensive instruction.

When the plans were completed they were outlined to high school principals, members of the board of public instruction, and school trustees. All groups pledged full cooperation The trustees readily assented to the use of two classrooms in a downtown junior high school, each Tuesday and Thursday evening

At first, CAP members agreed to do all the instructing. It soon became apparent that men with more advanced technical knowledge would be needed. Officials of Orlando Air Base and Army Air Forces School of Applied Tactics agreed to permit some of their technical officers to donate spare time if they wished. Several navigation and meteorological officers agreed to donate two evenings each week.

The setup looked perfect Now it became necessary to interest the 50 boys and girls to take the courses. The local high school principal was pessimistic.

"The boys and girls are enthusiastic about every new thing that comes along, and want to join it. You'll probably get a good crowd the first night. After that they'll drop out quickly," he remarked.

"All right, then," Dyer declared. "Let's go before the boys and girls at one of the high school assemblies Let's put the proposition squarely before them. At the start let them understand we're not fooling, we mean business Let's tell them honestly that we don't want them to take the courses unless they are serious, and that if they don't keep up to passing marks they'll be dropped as Cadets,"' he asserted.

When the CAP committee appeared before 1,400 high school students one morning, they minced no words. They brought mimeographed questionnaires which interested boys and girls were asked to fill out, only if they were serious about the matter. Those filing applications were given prepaid postal cards which parents or guardians were required to fill out granting permission for their son or daughter to attend the school. Parents and guardians were urged to attend along with their boys and girls.

How carefully the program had been designed, and how well it appealed to the youths became apparent in the initial enrollment Instead of 50 youths enrolling, 198 appeared the first night of classes. Two classrooms overflowed, and the halls of the school were jammed with prospective Cadets.

CAP members felt disinclined to turn the boys and girls away. They quickly revamped the program. School board trustees offered four more classrooms, a gymnasium and auditorium in the same junior high school building.

During the first semester various CAP members, including a woman member, acted as instuctors A local police official, graduate of a Red Cross first aid school, taught first aid.

When the first semester ended, average grades for the Cadets were 84 percent, higher than the

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HANDLING OF FIREARMS is taught in CAP school. Class work is supplemented by heavy range practice

AIR NAVIGATION classes are of major importance in the curriculum of these CAP pre-flight students.

CONTROL STICK OPERATION is the lesson for this Cadet Commander. Actual experience augments theoretical knowledge at the Orlando School.

average at the local high school. Six honor students in each class were awarded airplane trips as an incentive to other students to work harder during the next semester. Of the 198 who enrolled at the beginning, 156 completed the first semester, about 79 percent. CAP members had counted on a 60 percent dropout instead of 21 percent.

When the second semester opened, the entire 156 Cadets who had completed the first period were back in classes, plus 26 new Cadets selected from a long waiting list.

Army officials had become greatly interested in the school. Several young Air Corps officers began teaching the more technical subjects in the second semester. Lt. Col. William H. Fillmore, commandant of the Orlando Air Base, paid an official visit to the school.

"May I commend you and your staff for your patriotic, tireless and successful manner in which you are doing more than your bit to win the war on the home front. Your teamwork coefficient is an actuality," he declared.

Shortly after Col. Fillmore's visit, Army Air Corps sound movies were made available to the Cadets. They dramatized many of the subjects which were in the curriculum.

The first half of the program cost only $27.72, all of which had been paid from the Squadron treasury. All instruction had been donated, and school authorities asked no rental for use of the classrooms, gymnasium, auditorium and other facilities.

CAP members are not yet sure whether flight training and other advanced subjects can be offered the Cadets.

"Of this we are sure," Dyer declares. "We are providing fundamental instruction in aviation to these boys and girls, and they're soaking it up like sponges. What they learn in this Cadet School will be a solid foundation from which to carry on in civil or military aviation, in the air or on the ground."

CAP members sound a salient warning, however. It is this:

"The entire success of similar schools will depend largely on a positive program. Boys and girls will not stand for a wishy-washy program of instruction. And they will demand a teaching staff both adequate and capable of offering the highest quality of instruction."

Orlando's Cadet School may usher in an entirely new concept in the training of air personnel for the armed services or civil aviation. The Cadets have proved they want such training, and they have shown they can absorb it.

The project is certainly worthwhile and bears watching. It is hoped that similar enterprises will be inaugurated in other parts of the country. The youths have shown themselves serious, and fully capable of mastering the subjects being taught. It may be the answer to the world of flight to come.

PARADE OF POWER

★ ★ ★

IF YOU like to know what makes planes tick—the whys and hows of all that's newest in automatic devices, life saving contraptions, deadly weapons, and plane parts—you'll be really keen on the AAF Power Show which is currently featured at the New York Museum of Science and Industry and slated to stay until March.

This exhibit is keyed for civilians and shows the tremendous technical strides made by aviation under the stimulus of dire war-time necessity.

Equipment for the major exhibits has been supplied by the Air Service Command of the Army Air Forces, which directs the supply and maintenance of all AAF planes throughout the world and handles over 500,000 different kinds of items.

Several battle-scarred fighters bring the tumult of war to our ears right in the heart of Rockefeller Center. A stubby-nosed P-47 Thunderbolt holds court in the main rotunda. Its wing section is cut away so the .50 calibre machine guns may be seen.

High above, a P-39 Airacobra with spinning propeller looks down its narrow aristocratic nose at the milling spectators below. This plane is suspended from the ceiling with the famous 37 mm. cannon plainly visible in its nose.

The electrical system of a P-40 fighter presents a bewildering array of gadgets, levers, connecting mechanisms and vari-colored lights. Even the most uninitiated, upon beholding this labyrinth of controls, will find his fingers itching to try them out and see what happens. But he'd better learn what's what before he tries to assuage the itch in some real cockpit. This is a pretty serious business. The lights supply constant information to the pilot about his ship's performance. In addition to his instrument panel, the pilot has running, formation, and landing lights. Through his lighted gunsight he peers at enemy targets. The touch of a button on his control stick sends electric power through solenoids to fire his guns. Instrument panel switches give him the choice of

CONTINUED ON NEXT PAGE

AAF POWER SHOW features Republic Thunderbolt in main rotunda. Overhead is a Bell Airacobra. Technical exhibits line walls and staircases.

P-40 NOSE AND COCKPIT bearing insignia of Flying Tigers. You can bet the Japs don't feel so happy when they see these Zero-eaters coming.

AIR FORCE SHOW GETS ONCE-OVER from the Navy. This sailor appears deeply interested in the complicated electrical system of a P-40.

CLOSE ACQUAINTANCE with P-47 propeller awakens real respect.

guns he can fire. (Alternate firing cools guns between bursts.)

Many mechanical revelations are in store for the visitor. He may examine the hydraulic system of a B-25, which controls landing gear, wheels and flaps, and bomb bay doors. He will become acquainted with the far-famed, almost humanly sensitive "George," the automatic pilot which is now an incredible reality. He will study the Turbo-supercharger (which means superiority in aerial combat, for the plane with the highest ceiling has the advantage in any fray) and the latest oxygen system (so constructed that it is free from the dangers of explosion and fragmentation, in case it is struck by bullets). Aircraft engines of many types are there too, for all to see.

In full view is a Power Turret with its two .50 calibre machine guns which spit death from the sleek plexi-glass domes.

There is an extensive display of life saving and emergency equipment for various climates and conditions. Here is the "flotation suit" quilted with chicken feathers to give it buoyancy. Methods of parachuting supplies to marooned personnel are also illustrated.

Exciting in its implications is the cockpit section of a Curtiss P-40 fresh from the battle front and bearing the insignia of the noted Flying Tigers of China. Those vicious-looking teeth painted on the nose actually remind one more of a man-eating shark than of a Tiger—and you can bet this plane is a Zero-eating shark when it's in action!

Ah—and here is a Douglas A-20—a light bomber holding its own among all the lusty little fighters. Authentic bombs occupy the racks. Forward is the "greenhouse" (Bombardier's compartment) with its panel of switches by which the bombardier selects the bombs to be released.

Some splendid examples of aerial photography leave us literally gaping in amazement at the progress which has left our previous modest conceptions far behind.

Such are the highlights of this Power Show . . . and there's plenty more to see, as well. For those who will be in New York some time soon, this may be only an appetizer. For all who will not—we hope you've enjoyed this short visit. It's been fun having you with us.

FLY LEAVES

GLENN CURTISS—
Alden Hatch

This book is the biography of Glenn Curtiss and the story of those epic first days of the airplane.

Curtiss' revolutionary contributions to the staying success of the airplane—the aileron, the tricycle landing gear and the V8 water-cooled motor are fully discussed here. So are his feats in air and on water (he was the first man to fly from and land on water).

You are taken back to the Aerial Experiment Association, founded by Alexander Graham Bell, Glenn Curtiss (then a motorcycle manufacturer) and Lieutenant Thomas Selfridge, one of the first officers in the Army to foresee the military significance of aviation. This society was an invaluable sponsor of aerial study and investigation.

In World War I Glenn Curtiss' Jenny—JN-4, blazed its way in European skies, to military success. In World War II it's the Curtiss P-40 and the Curtiss dive bomber that have helped to make our air fleet formidable.

This book gives an excellently detailed background of aviation at the same time that it describes the life and achievements of one of our foremost leaders in aviation—a man who helped to make the airplane what it is. Julian Messner, Inc., 8 West 40th St., New York City. $2.50.

MILLION-MILER—
John R. Tunis

This is the story of Captain H. J. Zimmerman, chief pilot of the Atlantic Division of Transcontinental and Western Air, Inc., who has flown two million miles and spent 15,000 hours in the air!

Captain Zimmerman (who is now a Major—in the Air Force Ferrying Command) has a lot of "first's" to his credit. He piloted the first scheduled flight into La Guardia Field, New York, when it was opened to traffic in 1939. Back in 1934 he took up the first DC I. He was at the controls of the giant Boeing Stratoliner which set a transcontinental record on its first scheduled transport flight on its birthday trip in July, 1940.

It's a story of another American boy who just had to be a pilot—or else. If that's the way you feel too, you'd better get around to this book quick. Julian Messner, Inc., 8 West 40th St., New York City. $2.50.

A PILOT'S METEOROLOGY—
Charles Graham Halpine

The basic principles of meteorology—without mathematical formulae, advanced physics or differential equations—are presented here not for the meteorologist but for the pilot who has to cope with those weather conditions which the meteorologist predicts and describes. An exceedingly valuable "primer" for the pilot who wants to know the fundamentals about air currents and winds, air masses and clouds, who wants, in fact, to understand that upper part of the world where he spends so much of his time. D. Van Nostrand Co., Inc., 130 Church Street, New York, N. Y. $2.75.

SEMPER FIDELIS—
Keith Ayling

How is a Marine "built"? What makes him about the toughest fighter in the world, with leather lungs and steel ribs, a lion's heart, and a spirit that never says die? Would you really like to know? This book will tell you!

You'll read about their program of training—which includes, incidentally, about everything that a soldier needs to know in this highly technical war-age in defensive and aggressive action—from tending barrage balloons and flying gliders to fighting as Rangers or Paratroopers. You'll also get a dose—in print—of what it's like to walk through a jungle where Japs are tied in palm trees, so camouflaged you can't tell the difference between a Jap and the foliage, what the aerial combats over Midway were like and—yes—Wake Island! No history of the Marines is complete without a story of that rugged and glorious defense. Houghton Mifflin Company, 2 Park Square, Boston, Mass. $2.00.

THEORETICAL HYDRODYNAMICS—
L. M. Milne-Thompson

This book presents a clear and methodical introductory exposition of the mathematical theory of fluid motion, which will be useful in applications to both hydrodynamics and aerodynamics. The author is professor of mathematics in the Royal Naval

College, Greenwich, England. The book has grown out of his lectures to junior members of the Royal Corps of Naval Constructors on the theory of fluid motion. MacMillan Company, 60 Fifth Avenue, New York City. $8.75.

NAVAL AVIATION 1943—

This text has been prepared by the Training Division of the Bureau of Aeronautics, Navy Department. It discusses the designation of naval aircraft; pilot procurement; flight training; marine corps aviation; coast guard aviation; aircraft armament and communications, and other fields of technical information. A "must" for cadets and those who plan to fly and a worthwhile reference book for everyone. United States Naval Institute, Annapolis, Maryland. $2.00.

A MANUAL OF AIRCRAFT DRAFTING—

Carl Lars Svensen

Procedures which have become standardized in aircraft drafting rooms but have not been made generally available for reference use are discussed in this book, which is one of the first to efficiently cover the subject.

The drafting practices which have developed in aviation to meet the requirements of design layouts, specifications, etc. are explained.

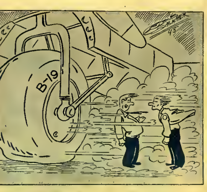
What's more, if you haven't had a course in mechanical drawing it doesn't matter. You will still be able to understand this book because the first chapters give the necessary instruction for the use of the graphic language. D. Van Nostrand Co., Inc., 130 Church St., New York City. $2.00.

PRINCIPLES OF AIRCRAFT ENGINES—

Bert A. Shields

A pilot has to know his engine. Any boy who hankers after flying will gain a fine preliminary knowledge of aircraft engineology from this book which is, incidentally, one of a series concerned with introductory aviation. The material is clearly and cleverly handled. McGraw Hill Book Co., 330 West 42nd St., New York City. $1.88.

The AIR NAVIGATION article, PLOTTING THE COURSE which appears on Page 27 of this issue, is the third of a series of eleven articles written by Commander Scott G. Lamb, U. S. N., which will appear consecutively in FLYING CADET. All eleven parts are published in book form by the Norman W. Henley Publishing Company. Copies of AIR NAVIGATION FOR BEGINNERS by Commander Lamb may be purchased at bookstores or from the Norman W. Henley Publishing Company, 17 West 45th Street, New York City, $1.50 postpaid.



"Hurricane nothing, it's a slow leak we have to fix."

CHANGE OF ADDRESS

If you are moving from one address to another, please notify us as promptly as possible in order to avoid delays or any copies of the magazine going astray. Notice of a change of address should be received by the publishers at least 30 days in advance. Always be sure to include in your notice both your old address and your new address. Flying Cadet, 420 Lexington Avenue, New York 17, N. Y.

FLYING CADET BY-LINES

ERIC SLOANE is a name familiar to all who are interested in aviation. Mr. Sloane, whose illustrations, quizzes and articles have been appearing in FLYING CADET, is both artist and author. He is a pioneer in the cloudscape as a new field of art and almost every well-known flier owns a Sloane painting.

As author, he is known for his CLOUDS, AIR AND WIND which is an accepted textbook in Army, Navy and technical schools, and for CAMOUFLAGE SIMPLIFIED. He also did BODY IN FLIGHT, a Technical Order for the Army Air Forces which describes the effects of flying on the human body. Other books are soon to appear.

He has illustrated YOUR WINGS, LET'S FLY, and many other aviation books, and has done murals and advertising art work for the aviation industry.

Mr Sloane studied at Yale and at the New York School of Fine and Applied Arts. He took up flying in 1930 and became interested in meteorology as a means of attaining authenticity in his cloud murals and paintings. He spent ten years studying clouds and cloudscapes at Taos, N. M. Mrs. Sloane, who has to her credit many hours in the air, has done much photographic research for her husband's cloudscapes.

QUIZ ANSWERS

Questions on Page 4

1, The wingspread of the Bell Airacobra is 29 ft. 8 inches 2, Increase of all speeds would be necessary to maintain flight in the thinner air encountered at high altitudes. 3, Millibars are used on aero weather maps 4, Thermals are rising warm air columns. 5, Kites would be in order in this gale of 47 to 57 mph wind. 6, Showers are indicated by these inverted triangles. 7, High explosives—Keep Away! 8, Don't Land! 9, 1.15 statute land miles equals a nautical mile.

Notice to Servicemen

Unless you are certain that your address will remain the same for an appreciable length of time, why not have FLYING CADET sent to your home address? In this way, you may be sure of receiving each issue regularly.

Frequent changes of address make it difficult to insure prompt and regular delivery of the magazine and may cause your copy to go astray.

Raring to go ... ts, as they crouch on the aircraft carrier deck, alert and waiting.